A

TREATISE

ON

ROADS.

LONDON:
Printed by A. SPOTTISWOODE,
New-Street-Square.

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TREATISE

ON

ROADS;

WHEREIN

THE PRINCIPLES ON WHICH ROADS SHOULD BE MADE

ARE EXPLAINED AND ILLUSTRATED,

BY THE

PLANS, SPECIFICATIONS, AND CONTRACTS

MADE USE OF BY

THOMAS TELFORD, ESQ.

ON THE HOLYHEAD ROAD.

BY

THE RIGHT HONOURABLE

SIR HENRY PARNELL, BART.

HONORARY MEMBER OF THE INSTITUTION OF CIVIL ENGINEERS, LONDON.

LONDON:

PRINTED FOR

LONGMAN, REES, ORME, BROWN, GREEN & LONGMAN,

PATERNOSTER-ROW.

1833.

London:
Printed by A. Spottiswoode,
New-Street-Square.

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NOTES.

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INTRODUCTION.

When the state of a society has arrived at a high degree of industry and wealth, so many persons, and such quantities of goods, are set in motion, for the purpose of administering to its business and its luxuries, that it becomes of the greatest importance to construct the public roads in such a manner as to admit of travelling with rapidity and safety, and of reducing the cost of the carriage of goods to the lowest possible point.

To explain how these objects can be most effectually secured is the purpose of the following pages.

The measures necessary to be taken for affording the means of travelling with rapidity and

safety, and of transporting goods at low rates of carriage, form an essential part of the domestic economy of every people. The making of roads, in point of fact, is fundamentally essential to bring about the first change that every rude country must undergo in emerging from a condition of poverty and barbarism. It is, therefore, one of the most important duties of every government to take care that such laws be enacted, and such means provided, as are requisite for the making and maintaining of well-constructed roads into and throughout every portion of the territory under its authority.

M. Storch most correctly says, that, "after giving protection to property and person, a government can bestow on a nation no greater benefit thàn the improvement of its harbours, canals, and roads."*

Speaking of roads, the Abbé Reynal justly remarks, "Let us travel over all the countries of the earth, and whenever we shall find no facility of travelling from a city to a town, or from a village to a hamlet, we may pronounce the people to be barbarians."

It has been well said by a writer in the first volume of the Communications to the Board of

* Cours d'Economie Politique, vol. i. p. 188.

Agriculture, that "the conveniencies and beneficial consequences which result from a free and easy communication between different parts of a country are so various, the advantages of them so generally and so extensively felt by every description of individuals from the highest to the lowest, that no labour or expense should be spared in providing them. Roads, canals, and navigable rivers, may be justly considered as the veins and arteries through which all improvements flow. How many places in almost every country might be rendered doubly valuable, if access to them were practicable and easy!"

Adam Smith says, "Good roads, canals, and navigable rivers, by diminishing the expense of carriage, put the remote parts of a country nearly on a level with those in the neighbourhood of a town; they are, upon that account, the greatest of all improvements."

The establishing generally throughout a country of perfect roads is an object of no small importance in regard to public economy. In proportion as roads are level and hard, there will be a saving of horse labour; fewer horses will be required; they will last longer, and a cheaper description of horse may be employed; less food will be consumed, and fewer servants will be wanted. In consequence of this reduction

of expense, the charges for travelling will be lowered, and also the rates for the carriage of goods. An aggregate saving of expense to the public will thus annually take place, amounting to a considerable sum, either to be applied to other expenses, or to the accumulation of the national capital.

Before proceeding to show what is necessary to be done to secure good roads in this country, it will be useful to mention the conduct of other nations in this branch of political economy.

A description of this kind may serve to give a better tone to the ideas of those country gentlemen who are the trustees of the interests of the public in its road concerns; and encourage them to form a larger and more correct conception of their duties and their responsibility.

The following quotations are taken from the French Encyclopædia, under the head of *Chemin.* The very interesting information they contain will be a sufficient apology for their length: —

"The police of roads does not begin to show itself as worthy of consideration until the prosperous times of Greece. The senate of Athens watched over them. The Lacedæmonians, Thebans, and other states, confided them to the care of the most eminent men. It does not, how-

ever, appear that this display of management produced any considerable effect in Greece. It was reserved for a commercial people to observe the benefits of facility of travelling and transporting goods; hence it is that the invention of paved roads is given to the Carthaginians.

"The Romans did not neglect the example of the Carthaginians, and that part of their labours is not the least glorious to this people. The first road they made was the *Via Appia*, the second the *Via Aurelia*, the third the *Via Flaminia*. The public and the senate held the roads in such estimation, and took so great an interest in them, that under Julius Cæsar the principal cities of Italy all communicated with Rome by paved roads.

"Their roads from that period began to be extended into the provinces.

"During the last African war, the Romans made a road with rectangular broken stones (de cailloux taillés en quarré), from Spain through Gaul to the Alps. Domitius Œnoberbus paved the *Via Domitia*, which led to Savoy, Dauphiny and Provence. The Romans made in Germania another *Via Domitia*.

"Augustus, when emperor, paid more attention to the great roads than he had done during his consulate. He conducted roads into the Alps;

his plan was to continue them to the eastern and western extremities of Europe. He gave orders for making an infinite number in Spain; he enlarged and extended the *Via Medina* to Gades. At the same time, and through the same mountains, there were opened two roads to Lyons; one of them traversed the Tarentaise, and the other was made in the Alphenin.

" Agrippa seconded Augustus ably in this part of his government. It was at Lyons he began the extension of roads throughout all Gaul.

" There are four of them particularly remarkable for their length, and the difficulty of the country through which they passed. One traversed the mountains of Auvergne, and penetrated to the bottom of Aquitaine. Another was extended to the Rhine at the mouth of the Meuse, and followed the course of the river, to the German Ocean; the third crossed Burgundy, Champagne and Picardy, and ended at Boulogne-sur-Mer; the fourth extended along the Rhone, entered the bottom of Languedoc, and terminated at Marseilles. From these principal roads there were an infinity of branch roads, namely, to Tréves, Strasburg, Belgrade, &c.

" There were also great roads from the eastern provinces of Europe to Constantinople, and into Croatia, Hungary, Macedonia, and to the mouth of the Danube at Torres.

"The seas were able to cut across the roads undertaken by the Romans, but not to stop them. Witness Sicily, Corsica, Sardinia, England, Asia and Africa, the roads of which countries communicated with the roads of Europe by the nearest ports. What labours! when we embrace in one point of view the extent and the difficulties which opposed themselves; the forrests opened, the mountains cut through, the hills lowered, the valleys filled up, the marshes drained, and the bridges which were built!" *

The following description of the manner in which the Roman roads were made, is taken from the same work: —

"Les grands chemins étoient construits selon la diversité des lieux: ici ils s'avançoient de niveau avec les terres; là ils s'enfonçoient de niveau avec les terres; là ils s'enfonçoient dans les vallons; ailleurs ils s'élevoient à une grande hauteur; partout on les commençoit par deux sillons tracés au cordeau; ces parallèles fixoient la largeur du chemin; on creusoit l'intervalle de ces parallèles; c'étoit dans cette profondeur qu'on étendoit les couches des matériaux du chemin. C'étoit d'abord un ciment de chaux et de sable de l'épaisseur d'un pouce; sur ce

* French Encyclopædia, folio edit. vol. iii. p. 387.

ciment, pour première couche, des pierres larges et plates, de six pouces de hauteur, assises les unes sur les autres, et liées par un mortier le plus dur; pour seconde couche, une épaisseur de huit pouces de petites pierres rondes, plus tendres que le caillou, avec des tuiles, des maellons, des plâtras, et autres décombres d'édifice, le tout battu dans un ciment d'alliage; pour la troisième couche, un pié d'épaisseur d'un ciment fait d'une terre grasse, mêlée avec de la chaux; ces matières intérieures formoient depuis trois piés jusqu'à trois piés et demi d'épaisseur. La surface étoit de gravois lié par un ciment mêlé de chaux; et cette croûte a pu résister jusqu'à présent en plusieurs endroits de l'Europe."

"The Roman roads," says Mr. Tredgold, "ran nearly in direct lines; natural obstructions were removed or overcome by the effort of labour or art, whether they consisted of marshes, lakes, rivers, or mountains. In flat districts, the middle part of the road was raised into a terrace.

"In mountainous districts, the roads were alternately cut through mountains and raised above the valleys, so as to preserve either a level line or a uniform inclination. They founded the road on piles where the ground was not solid, and raised it by strong side walls, or by arches and piers where it was necessary to gain eleva-

tion. The paved part of the great military roads was sixteen Roman feet wide, with two side ways, each eight feet wide, separated from the middle way by two raised paths of two feet each."*

The funds for making roads were so well secured and so considerable, that the Romans were not satisfied to make them convenient and durable, but they also embellished them.

" They had columns placed from mile to mile to mark the distance of one place from another; blocks of stone for foot travellers to rest upon, and to assist horsemen to mount their horses; and also temples, triumphal arches, mausoleums, and military stations.

" Such was the solid construction of the Roman highways, that their firmness has not entirely yielded to the effect of fifteen centuries.

" They united the subjects of the most distant provinces by an easy and familiar intercourse; but their primary object was to facilitate the marches of their legions."†

After enumerating all the cities in the different parts of the empire, Mr. Gibbon says, " All these cities were connected with each other and

* See Tredgold on Railways, p. 6.

† See Bergier, Histoire des grands Chemins de l'Empire Romain, liv. ii. cap. 1. p. 28.

with the capital by the public highways, which, issuing from the forum of Rome, traversed Italy, pervaded the provinces, and were terminated only by the frontiers of the empire.

"If we carefully trace the distance from the wall of Antoninus (in Britain) to Rome, and from thence to Jerusalem, it will be found that the great chain of communication from the north-west to the south-east part of the empire was drawn out to a length of 4080 Roman miles, or 3740 English miles. The public roads were accurately divided by milestones, and ran in a direct line from one city to another, with very little respect for the obstacles either of nature or private property: mountains were passed, and bold arches thrown over the broadest and most rapid streams. The middle part of the road was raised into a terrace, which commanded the adjacent country, and consisted of several strata of sand, gravel, and cement, and was paved with large stones, which in some places near the capital were of granite."

The following are Mr. Pinkerton's observations on the Roman roads: —

"One of the grand causes of the civilisation introduced by that ruling people (the Romans) into the conquered states, was the highways, which form, indeed, the first germ of national

industry, and without which neither commerce nor society can make any considerable progress. Conscious of this truth, the Romans seem to have paid particular attention to the construction of roads in the distant provinces; and those of England, which may still be traced in various ramifications, present a lasting monument of the justice of their conceptions, the extent of their views, and the utility of their power. A grand trunk, as it may be called, passed from the south to the north, and another to the west, with branches in almost every direction that general convenience and expedition could require. What is called Watling Street led from Richborough, in Kent, the ancient Rutupiæ, north-east, through London to Chester. The Ermine Street passed from London to Lincoln, thence to Carlisle, and into Scotland.

" The Foss way is supposed to have led from Bath and the Western regions, north-east, till it joined the Ermine Street. The last celebrated road was Ikeneld, or Ikneld, supposed to have extended from near Norwich, southward, into Dorsetshire." *

Mr. Eustace says, in his Classical Tour, " Thus the civilised world owes to the Romans the first establishment and example of a commodious in-

* Pinkerton's Geography, vol. i. p. 20.

tercourse; one of the greatest aids of commerce and means of improvement that society can enjoy."

He further says, "The barbarians who overturned the Roman power were for many ages so incredibly stupid as to undervalue this blessing, and almost always neglected, and sometimes wantonly destroyed the roads that intersected the provinces which they had invaded. To this day the different governments of Germany (except Austria), Spain, Portugal, Sicily, and Greece, are still so immersed in barbarism, as to leave the traveller to work his way through their respective territories, with infinite fatigue and difficulty, by tracks and paths oftentimes almost impracticable."*

Among modern nations, France is one of the most distinguished for the attention that she has bestowed in forming numerous roads.

The following account of her roads is taken from Peuchet's Statistical Account of France:—"The origin of our principal roads is generally attributed to Philip Augustus; it was under his reign, and by his orders, that the city of Paris began to be paved.

"Sully took great interest in the improve-

* Vol. iii. p. 178.

ment of the roads. He first introduced the practice of planting trees on the sides of them, and established regular funds for their repair. Colbert neglected nothing to advance the extension of roads throughout France; and M. Desmartis, who succeeded him, caused the road from Paris to Orleans to be made. He was the founder of the corps of engineers, appointed to superintend the works belonging to the roads. Under the administration of the Duke de Noailles, the roads were improved and carried through the provinces. In 1726 the department of the *Ponts et Chaussées* fell into great disorder, and was in want of sufficient funds, but the Director-general, the brother of the celebrated Cardinal Dubois, recommenced the repairs of them, and continued them with great regularity.

" Under the administration of M. de Trudaine, in 1787, a number of new roads were made. He established the *Ecole des Ponts et Chaussées*, under M. Perronet, as chief engineer, and at his death he left to this school his manuscripts and library. This school is under the minister of the Home Department; the scholars are fifty in number; these are selected from the Polytechnic School, and receive an allowance of seventy-five francs a month.

"The roads of France were divided at this time into four classes, according to their importance, and the breadth that is given to them. The first class comprised the great roads which traverse the whole of France, from Paris to the principal cities and the ports; the second class, the roads between the provinces and principal cities; the third class, the roads between the principal towns in the same province and the neighbouring provinces; and the fourth class, the roads between small towns and villages.

"By an order of council of the 6th of February, 1776, the breadth of the first class was fixed at forty-two feet (French) between the fences; of the second at thirty-six feet; of the third at thirty feet; and of the fourth at twenty-four feet.

"The roads have since been divided into three classes, not according to their breadth, but their direction." *

All the principal roads of France are under the management of Government. The department of the *Ponts et Chausseés* has the care of them. In the year 1830, the sum of £1,800,000 was granted by the chambers for their support.

Notwithstanding, however, the attention which has been paid to the roads in France, the actual

* Peuchet, p. 458.

state of them, with regard to their number, extent, and condition, is evidence of the system of management being extremely imperfect.

With the exception of those parts of the main roads leading from Paris which are paved, the roads are weak and rutted. In those districts where they are repaired with gravel, they are almost impassable in winter; the diligences with six horses can with difficulty travel four miles an hour. In other districts, where the materials are harder, there is seldom to be seen a road with a smooth surface and of sufficient strength. There are very extensive tracts of the kingdom wholly without any regularly formed roads; and, therefore, however valuable the efforts of the statesmen of France may have been in carrying the progress of road-making to the point at which it has arrived, there is still wanting some new plan of legislation, by which good roads may be made, not only from one town to another, but into and through every commune in France.

In Spain, the *caminos reales*, or king's highways, are not numerous, nor are they kept in good repair. Taking Madrid as a point of departure, there are two good roads to Burgos; one passing through Valladolid, and the other through Aranda de Duero. From Burgos, the road is continued by Vittoria and Irun to France.

Both these roads are in tolerable repair. From Valladolid a good road has been made by Valentia and Reynosa to Santander. There are two good roads to Bilboa; one by Miranda, the other by Vittoria.

To the northward, there is a *camino reale* through Gallicia to Corunna and Ferrol; but in such a state of disrepair, as to be impassable in numerous places for loaded carriages; but attempts are now making to improve it. In Catalonia the roads are comparatively numerous and good.

The road from Saragosa to Barcelona has lately been put in repair, and a diligence was established upon it in the beginning of the year 1831.

The other roads which are traced upon maps of Spain may be divided into three classes:—

1st, Roads which have originally been made and covered with road metal; 2d, Roads across the plains and through the valleys, formed by the tracts of the country carts, and which have only, in a few places, been artificially constructed; and, 3dly, the mule roads or paths, worn by the feet of the mules travelling over the mountains during a long series of years.

The revenue applicable to the construction and repairing of the roads is derived, 1st, from

tollgates; and 2d, from local taxes. Upon all the practicable roads tolls are established at the distance of ten or twelve English miles.*

The following remark on the roads of Spain is taken from the Edinburgh Review, for July, 1832:—"Another check upon agriculture is, that with the exception of some few high roads, which are sufficiently insecure, there exists scarce a waggon or cart track throughout Spain. All means of transport are therefore dear; and in Salamanca, it has been known, after a succession of abundant harvests, that the wheat has actually been left to rot, because it would not repay the cost of carriage. About 90,000*l.* is the average annual expenditure upon the roads in Spain.†

In the most populous districts of the German and Russian dominions, the chaussée, or paved road, similar to that of France, is common; but over a great part of these countries the roads are little more than formed, being almost without any prepared surface. The roads in Holland are generally carried in undeviating straight lines along that low and flat country, between a double row of trees, with a ditch on each side. The

* See Foreign Quarterly Review, vol. v. p. 82.
† Vol. lxv. p. 448.

Dutch are at great pains in preparing a firm foundation for their roads; they are then built with their bricks, called *clinkers*, which are laid in lime; their longest direction being laid across the road. The Swedes have long had the character of being excellent road engineers. Good rock is very generally met with in Sweden, and they spare no pains in breaking it small; their roads are spacious and smooth.

Where the country has been opened in Russia the roads are formed on scientific principles, but there are few of them. In the United States of America the roads have latterly been much improved; the principal lines are similar to the generality of English roads. Italy still preserves its celebrity for interior communication.*

The little attention that was paid in former times to the roads of England is made evident by a proclamation of Charles the First, issued in 1629, confirming one of his father's, in the twentieth year of his reign, for the preservation of the roads of England, commanding "that no carrier or other person whatsoever shall travel with any waine, cart, or carriage with more than two wheels, nor with above the weight of twenty

* The foregoing description of foreign roads is taken from Mr. Stevenson's article on roads in the Edinburgh Encyclopædia.

hundred, nor shall draw any waine, cart, or carriage, with more than five horses at once."*

The first attempt to put the roads into order occurred when the turnpike system was introduced. The ancient method employed to mend roads in England, until after the restoration of King Charles II., was by a pound rate in the respective counties on the landholders; and by the supplying of carts and horses of parishes, for a limited number of days. But when, after the last named period, commerce was become so generally increased, and in consequence thereof wheel-carriages and pack-horses were so extremely multiplied, the first turnpike road was established by law (the 16 Charles II. cap. 1. anno 1653), for taking toll of all but foot passengers on the northern road through Hertfordshire, Cambridgeshire, and Huntingdonshire; which road was then become very-bad, by means of the great loads of barley and malt, &c. brought weekly to Ware in waggons and carts, and from thence conveyed by water to London. "These roads," says the act, "were become so ruinous and almost impassable, that the ordinary course appointed by all former laws and statutes of this realm is not sufficient for the effectual re-

* Anderson's Commerce, vol. xix. p. 130.

pairing of the same, neither are the inhabitants, through which the said roads lie, of sufficient ability to repair the same," &c. &c. Wherefore three tollgates were erected, one for each of these three counties, viz. at Wadesmill, Caxton, and Stilton.*

It was not, however, till after the peace of 1748 that any thing like a great exertion was made to redeem the public highways from the wretched state in which they had always been.

The following description of the roads is taken from Mr. M'Culloch's Dictionary of Commerce:—

"It is not easy for those accustomed to travel along the smooth and level roads by which every part of the country is now intersected to form an accurate idea of the difficulties the traveller had to encounter a century ago.

"Roads were then hardly formed, and in summer not unfrequently consisted of the bottoms of rivulets. Down to the middle of the last century most of the goods conveyed from place to place in Scotland, at least where the distances were not very great, were carried, not by carts or waggons, but on horseback. Oatmeal, coals, turf, and even straw and hay, were

* Anderson's Commerce, vol. v. p. 44.

conveyed in this way. At this period, and for long previous, there were a set of single-horse traffickers (cadgers) that regularly plied between different places, supplying the inhabitants with such articles as were then most in demand, as salt, fish, poultry, eggs, earthenware, &c.; these were usually conveyed in sacks or baskets, suspended one on each side the horse. But in carrying goods between distant places it was necessary to employ a cart, as all that a horse could carry on his back was not sufficient to defray the cost of a long journey. The time that the *carriers* (for such was the name given to those that used carts) usually required to perform their journeys seems now almost incredible. The common carrier from Selkirk to Edinburgh, *thirty-eight* miles distant, required a *fortnight* for his journey between the two places, going and returning! The road was originally among the most perilous in the whole country: a considerable extent of it lay in the bottom of that district called the Gala Water, from the name of the principal stream, the channel of the water being, when not flooded, the track chosen as the most level and easiest to travel in. Even between the largest cities the means of travelling were but little superior. In 1678 an agreement was made to run a coach between Edinburgh and

Glasgow, a distance of forty-one miles, which was to be drawn by *six* horses, and to perform the journey from Edinburgh to Glasgow and back again in six days. Even so late as the middle of the last century, it took a day and a half for the stage coach to travel from Edinburgh to Glasgow, a journey which is now accomplished in four and a half or five hours.

"So late as 1763 there was but one stage coach from Edinburgh to London, and it set out only once a month, taking from twelve to fourteen days to perform this journey! At present, notwithstanding the immense intercourse between the two cities, by means of steam packets, smacks, &c., six or seven coaches set out each day from the one or the other, performing the journey in from forty-five to forty-eight hours."*

Mr. Arthur Young, in his Six Months' Tour, published in 1770, gives the following account of some of the roads in the north of England: — "*To Wigan.* Turnpike. — I know not in the whole range of language terms sufficiently expressive to describe this infernal road. Let me most seriously caution all travellers who may accidentally propose to travel this terrible country

* M'Culloch's Dictionary of Commerce, art. Roads.

to avoid it as they would the devil, for a thousand to one they break their necks or their limbs, by overthrows or breakings down. They will here meet with ruts, which I actually measured four feet deep, and floating with mud only from a wet summer; what therefore must it be after a winter? The only mending it receives is tumbling in some loose stones, which serve no other purpose than jolting a carriage in the most intolerable manner. These are not merely opinions, but facts; for I actually passed three carts, broken down, in these eighteen miles of execrable memory. *To Warrington.* Turnpike. — This is a paved road, most infamously bad; any person would imagine the people of the country had made it with a view to immediate destruction! for the breadth is only sufficient for one carriage, consequently it is cut at once into ruts; and you may easily conceive what a break down, dislocating road ruts, cut through a pavement, must be.

"*From Dunholm to Knutsford.* Turnpike. — It is impossible to describe these infernal roads in terms adequate to their deserts. *To Newcastle.* Turnpike. — A more dreadful road cannot be imagined. I was obliged to hire two men at one place to support my chaise from overturning. Let me persuade all travellers to

avoid this terrible country, which must either dislocate their bones with broken pavements, or bury them in muddy sand.

"It is only bad management that can occasion such very miserable roads, in a country so abounding with towns, trade, and manufactures."*

Mr. Chambers says, in his estimate, "Turnpikes which we saw first introduced soon after the Restoration were erected slowly, in opposition to the prejudices of the people. The act which for a time made it felony at the beginning of the reign of George the Second to pull down a tollgate was continued as a perpetual law before the conclusion of it. Yet the great roads of England remained almost in their ancient condition, even as late as 1752 or 1754, when the traveller seldom saw a turnpike for 200 miles after leaving the vicinity of London."†

After 1760 the general spirit of improvement led to that of the roads; and in the fourteen years from that period, to 1774, no less than 452 Turnpike Acts were passed. Since that year a number of Turnpike Acts have continued to be passed, as will appear from the following table‡:—

* Vol. iv. pp. 430. 434. † P. 124.

‡ Encyclopædia Brit. art. England, vol. iv. p. 112. Second Supplement.

In eight years, from

1785 to 1792	-	-	302
1792 to 1800	-	-	341
1800 to 1809	-	-	419

In every year since 1809 the establishing of turnpike roads has gone on progressively, till they have extended to nearly 23,000 miles.

But although this turnpike system has led to the making of many new roads, and to the changing of many old ones, into what may be called good roads, in comparison with what they formerly were, this system has been carried into execution under such erroneous regulations, and the persons who have been intrusted with the administration of them have uniformly been either so negligent, or so little acquainted with the business of making or repairing roads, that at this moment it may be stated, with the utmost correctness, that there is not a road in England, except those recently made by some eminent civil engineers, which is not extremely defective in the most essential qualities of a perfect road.*

* Mr. Edgeworth says, in his *Essay on the Construction of Roads*, published in 1813, " Since this Essay was written, I have visited England, and have found, on a journey of many hundred miles, scarcely twenty of well made road. In many parts of the country, and especially near London, the roads are in a shameful condition; and the pavement of London is utterly unworthy of a great metropolis." Introduction, p. 7.

With regard to the lines of direction of the turnpike roads, they evidently have not been laid out according to any fixed principle; they are, in fact, precisely the identical lines, almost in every instance, which formed the footpaths of the aboriginal inhabitants of the country.

The following passage is taken from a pamphlet, called "The Landed Property of England:"—"Most of the old roads of the kingdom (the remains of the Roman ways excepted) owe their present lines to particular circumstances. Many of them were, no doubt, originally footpaths; some of them, perhaps, the tracks of the aboriginal inhabitants, and these footpaths became, as the condition of society advanced, the most convenient horsepaths. According as the lands of the kingdom were appropriated, the tortuous lines of road became fixed and unalterable, there being no other legal lines left for carriage roads, and hence the origin of the crookedness and steepness of existing roads."

The crookedness and steepness in numerous places, at this moment, of almost every great road, is thus accounted for. These defects are attended with great inconvenience and danger to travellers, and are quite disgraceful to the national character.

As many other great defects exist in all the principal roads, it is to be hoped, that at length

the attention of the public and of government will be roused, and seriously and effectually applied to bring about a proper remedy. These defects are, in point of fact, so numerous and so glaring, that it is quite evident that the true principles of the art of road-making have not yet been followed. The breadth of a road is seldom defined to a regular number of feet by straight and regular boundaries, such as fences, foot-paths, mounds of earth, or side channels. The transverse section of the surface, when measured, is rarely to be found of a regular convexity. The surface of all the roads, until within a few years, was every where cut into deep ruts, and even now, since more attention has been paid to road works, though the surface is smoother, the bed of materials which forms it is universally so thin, that it is weak, and consequently exceedingly imperfect. Drainage is neglected; high hedges and trees are allowed to intercept the action of the sun and wind in drying the roads; and many roads, by constantly carrying off the mud from them for a number of years, have been sunk below the level of the adjoining fields, so that they are always wet and damp, and extremely expensive to keep in order, owing to the rapid decay of the materials which are laid upon them.

The business of road-making in this country has almost entirely been confined to the exclusive management of individuals wholly ignorant of the scientific principles on which the making of good roads depends. It has received, till very lately, little attention from the scientific world; so little, indeed, that the primary and indispensable objects of providing a dry and sound foundation for the surface materials, and of giving the surface a regular convexity, have not, till within a short time ago, been recognised and explained by any scientific rules whatever. Although various select committees of the House of Commons have been appointed to take into consideration the state and condition of the roads, it does not, however, appear that any system for forming roads on scientific principles was suggested by them. On the contrary, the approbation expressed in their reports of the doctrines of a modern publication as comprising a perfect system of road-making, shows that they were not qualified for this task: for nothing, in point of fact, can be more opposed to the principles of science with respect to moving bodies, such as carriages, on roads, than what is recommended in this work as the perfection of road-making. This will be fully explained in the second chapter.

The foreign scientific traveller must be astonished to find that a nation like England, which displays such an extent of science on its canals, docks, bridges, and other public works, should exhibit in its roads such great imperfections. It must, in truth, be admitted, that the present and past state of the roads of England does not do credit to the wisdom of her laws respecting them, or to the care and skill of those who have been intrusted with the management of them.

While, during a considerable number of years, every improvement which depended on the industrious classes has made immense progress, the improvement of roads, the management of which the laws have vested in the hands of the land proprietors, made no advancement at all until very recently.

It is only about twelve years ago that the land proprietors seem to have begun to comprehend the value of good roads, and to be aware that large funds and a considerable share of science and constant attention are necessary to bring them into a perfect state.

At the present time, although the country gentlemen are somewhat more active and better informed, the degree of improvement which they have introduced is little more than the palliation

of a great evil, and goes but a short way towards securing that perfection which ought to be universally introduced.

While, however, England has been content to suffer her roads to be in so defective a state, Scotland and Ireland have acted far otherwise, and for a long time have had the benefit of a more improved system.

Lord Daer, eldest son of the Earl of Selkirk, about the year 1790, introduced into Scotland, and more especially through Galloway, the practice of laying out roads with the spirit level. The road from Dumfries to Castle Douglas was traced out by him, so as to have no greater inclination than 1 in 40, although passing through a very hilly country. Mr. Abercromby pursued, as a regular profession, the business of making roads. He laid out the road from Kinross to Perth, and by following the valleys, obtained an excellent line, instead of one passing over a succession of very steep hills. He also laid out the road from Perth to Dunkeld. In all cases he acted on the principle of never making a road to ascend a single foot without its being absolutely unavoidable; and this he accomplished by taking advantage of the valleys of the country, and skilfully cutting through high banks and filling hollows.

Mr. Abercromby made all his roads with stones broken very small. This practice had long existed in Scotland, and is recommended by the old writers on roads in France.

Since his time, many other good road-makers in Scotland have followed the same rules; so that Scotland has been making great progress for a number of years in establishing excellent roads.

In Ireland the abolition of the system of statute labour in 1763, and the placing of the business of making roads under the grand juries, immediately led to a great improvement in them; for, notwithstanding the abuses which have attended the exercise of the powers of the grand juries in money matters, the general result has been the establishing of good roads throughout the whole kingdom.*

Mr. Arthur Young, in his Tour in Ireland, says, "For a country so far behind us as Ireland to have got suddenly so much the start of us in the article of roads, is a spectacle that cannot fail to strike the British traveller;" and, in speaking of the law to which this was owing, he says, "The original act was passed but seventeen

* By 3 Geo. 3. c. 14., 1763, all former road acts from 11 James 1., in 1614, to 3 Geo. 3. c. 8. inclusive, were repealed, and the statute labour, or six days' system, abolished.

years ago, and the effect of it in all parts of the kingdom is so great, that I found it perfectly practicable to travel upon wheels by a map. I will go here, I will go there; I could trace a route upon paper as wild as fancy could dictate; and every where I found beautiful roads, without break or hinderance, to enable me to realise my design."

"What a figure would a person make in England who should attempt to move in that manner, where the roads, as Dr. Burn has very well observed, are almost in as bad a state as in the time of Philip and Mary.

"Arthur French of Moniva was the worthy citizen who first brought this excellent measure into parliament. Before that time the roads, like those of England, remained impassable under the miserable police of the six days' labour.

"Similar good effects would here flow from adopting the measure which would ease the kingdom of a great burden in its public effect absolutely contemptible."*

One of the greatest efforts which has been made in modern times by the legislature, to afford, on an extensive scale, to a part of the pub-

* A. Young, Tour in Ireland, vol. ii. p. 56.

lic, the benefit of improved communication, is the plan that was adopted in 1803 for making roads in the Highlands of Scotland. Commissioners were appointed in that year for making these roads. The expense was defrayed in equal portions by grants of Parliament and local contributions. The operations were conducted by Mr. Telford; and the result has been the constructing of 875 miles of road in every respect suitable to the country, and the building of 1117 bridges. These roads traverse the Highlands of Scotland in all directions; and, although the whole region consists of high mountains, the lines of road have been laid out with so much science, that the inclinations are every where moderate.

Next to the tracing of these roads, the principal merit consists in the forming and draining of them in such a manner as to place them out of the reach of all injury from the torrents of water to which they would otherwise be exposed.

In the districts between Glasgow, Cumbernauld, and Carlisle, upwards of 150 miles of new lowland roads have been made by Mr. Telford, acting under the same commission. But it was not until Mr. Telford was employed by the commissioners appointed by Parliament, in 1815,

for improving the Holyhead road, that he had an opportunity of carrying into execution a plan of road-making suitable to a great traffic on completely perfect principles. In that year, a sum of money having been voted by Parliament for the improvement of the Holyhead road, Mr. Telford was consulted by the commissioners with respect to the best plan of accomplishing the object Parliament had in view. He strongly recommended that he should be allowed, if employed by them, to execute all the new works upon this line of road in the most substantial and perfect manner, in consequence of its great importance from being the main communication between England and Ireland.

The commissioners having adopted Mr. Telford's advice, and Parliament having continued to grant further sums of money, an extent of eighty-two miles of new road has been made by him through North Wales, between Chirk and Holyhead: three miles between Chirk and the village of Gobowen, near Oswestry, and seven miles on the Holyhead and Chester road. Thirty-one miles have also been made by Mr. Telford at various places on the Holyhead road between London and North Wales, with money advanced to the Parliamentary Commis-

sioners, on loan, by the Commissioners for giving Employment to the Poor. These roads have been constructed in the most substantial manner. A foundation of rough pavement has been made as a bed to support the surface materials. They are uniform in breadth and superficial convexity. They are completely drained, and when carried along the face of precipices, they are protected by strong walls. They are acknowledged, by all persons competent to form a correct judgment on works of this kind, to be a model of the most perfect road-making that has ever been attempted in any country.

The obvious utility of a work on road-making, explaining the principles on which this business should be carried on, and containing an illustration of those principles by a reference to the plans, specifications, and contracts which have been made use of in constructing this extent of new road, through a country presenting every kind of difficulty, has suggested the present publication. The object of it is to point out, in a clear and concise nanner, the best method of tracing out and constructing roads, under every variety of circumstances; and it is confidently expected, that the course which has been pursued of proceeding on experience by referring

to the identical plans, specifications, and contracts by which so great an extent of perfect road has been successfully made, will be found to have attained this object.*

* Extract from Mr. Telford's first Annual Report on the Holyhead Road, dated May 4. 1824, p. 17.: —

"SHREWSBURY TO HOLYHEAD.

"This portion of the great Irish road having been originally constructed in a very imperfect manner, was, till within the last five years, one of the worst roads in the kingdom. Through North Wales, in particular, no attention whatever had been paid to the essential points of a good road; it was narrow and crooked, hills had been passed over, and valleys were crossed without any regard to inclinations: no solid foundation was prepared; a very superficial coating of very bad stones or gravel was all that covered the soil; the transverse sections were often just the reverse of what they ought to be; the draining was miserably defective, and either no protecting fences, or very weak ones, existed along steep hill-sides and tremendous precipices.

"On this district there were no less than seven distinct Trusts; the revenue arising from the tolls being very limited, the trustees could not afford to employ persons whose education and previous pursuits qualified them to act as surveyors. The consequence was, that the road got into unskilful hands, and its state of repair was just as bad as the principle of its construction.

"The increasing importance of this line of communication at length attracted the attention of Parliament. I was directed to make a survey of it in 1810; and, it having been satisfactorily shown to the successive Committees of the House of Commons, that the country through which the road passed did not in itself possess the means of providing funds for effecting any essential improvement, an Act of

Parliament was passed in 1815, empowering commissioners, therein named, to expend the sum of 20,000*l.* in making such alterations as they might deem expedient.

"Under the power of this Act (the 55th Geo. 3. c. 152.) the commissioners commenced their operations in the autumn of 1815; and, according as further grants were from time to time voted by Parliament, the road progressively assumed its present character. Those parts which had been the most inconvenient and dangerous have been changed to perfect specimens of what roads ought to be; steep declivities have been reduced to perfectly easy inclinations; and narrow, crooked, ill-protected portions have been converted into broad, safe, smooth, and well-constructed roads.

"The value of these improvements was felt and appreciated; and it became of the highest importance to preserve them in a perfect state, by providing an efficient system of management.

"By the Act of the 55th Geo. 3. c. 152. the new pieces of road, when completed, were to be made over to the local trustees, to be by them repaired and maintained. But the local Acts were imperfect; the old tolls too low; every Trust deeply in debt, and the mode of management not so perfect as it ought to be. Under these circumstances, it was thought advisable to apply to Parliament for an Act to secure to the public the lasting benefits of those improvements, by placing them under the care of one Board of Commissioners.

"Accordingly, in May, 1819, the Act of the 59th Geo. 3. c. 30. was passed, in which six Trusts between Shrewsbury and Bangor were consolidated into one, and vested in fifteen commissioners therein named. The operations of this Act commenced from the first day of August following; and from that period a totally new system has been adopted on the whole line of road. At the first meeting of the commissioners they appointed a professional engineer as their general surveyor, also a clerk and a treasurer, and fixed upon a plan of management, of which the following is an outline.

"The total distance from Shrewsbury to Bangor Ferry, being 85 miles, was divided into three districts; the first, being 23 miles, extending from Shrewsbury to the boundary between Shropshire and Wales, at Chirk Bridge; the second, of 30 miles, from Chirk Bridge to Cernioge; and the third, of 32 miles, from Cernioge to Bangor Ferry.

"Over each of these districts an assistant surveyor or inspector was appointed, care being taken to select these officers from good practical workmen. Under these inspectors, a working foreman was placed on every four or five miles, with such a number of labourers under his charge as were sufficient for maintaining the road in proper repair.

"It was ordered that the labourers should be, as much as possible, employed by task, in quarrying rock, gathering field stones, getting gravel, breaking stones, scraping the road, loading materials into carts, and all works that are reducible to measure.

"The duties of the general surveyor and clerk were, to go along the line every four weeks, the surveyor to examine the practical operations, settle all acconnts with each inspector, and give the clerk a certificate, showing all the money due. The clerk to collect the tolls, and to pay every one what appeared to be owing by the surveyor's certificate, and lodge the balance of his receipts with the treasurers, Messrs. Beck and Co. of Shrewsbury."

CHAPTER I.

RULES FOR TRACING THE LINE OF A NEW ROAD.

This business of tracing the line of a road should never be undertaken without the assistance of instruments; and all local suggestions should be received with extreme caution.

To guard against errors in this important point, it is essentially necessary not to trust to the eye alone, but in every case to have a survey made of the country lying between the extreme points of the intended new road. For this purpose an experienced surveyor should be employed to survey and take the levels of all the various lines that, on a previous perambulation of the country, appear favourable. It is only by such means that the best line can be determined. These surveys should be neatly and accurately protracted and laid down on good paper, on a scale of sixty-six yards to an inch for the ground plan, and of thirty feet to an inch for the vertical section.

The map should be correctly shaded, so as to exhibit a true representation of the country, with

all its undulations of high grounds and valleys, streams and brooks, houses, orchards, churches, ponds of water adjacent to the line of road; and all other conspicuous objects should also be laid down in the map. A vertical section should be made, and the nature of the soil or different strata should be shown over which each apparently favourable line passes, to be ascertained by boring; for it is by this means alone that the slopes at which the cuttings and embankments will stand can be determined and calculated. If it be necessary to cross rivers, the height of the greatest floods should be marked on the sections; and the velocity of the water, and the sectional area of the river, should be stated.

If bogs or morasses are to be passed over, the depth of the peat should be ascertained by boring; and the general inclination of the country for drainage should be marked.

All the gravel-pits or stone quarries contiguous to the line should be described on the map, with the various roads communicating with them; and the existing bridges over the streams or rivers which are immediately below the proposed point of crossing them should be carefully measured, and the span, or waterway, stated on the section.

These preliminary precautions are absolutely necessary, to enable an engineer to fix upon the best line of road, with respect to general direction, and longitudinal inclination. Without the unerring guide of actual measurement and calculation, all will be guess and uncertainty.

It may be laid down as a general rule, that the best line of road between any two points will be that which is the shortest, the most level, and the cheapest of execution: but this general rule admits of much qualification; it must, in many cases, be governed by the comparative cost of annual repairs, and the present and future traffic that may be expected to pass over the road. Natural obstructions also, such as hills, valleys, and rivers, will intervene, and frequently render it necessary to deviate from the direct course.

HILLS.

In every instance of laying out a road in a hilly country, the spirit-level is essentially necessary to show the proper line of road to be selected. The general rule to be followed in surveys is to preserve the straight line, except when it becomes necessary to leave it to gain the rate of inclination that may be considered proper to be obtained, without expensive excavations and embankments. When a devi-

ation is made for this purpose, it becomes necessary to proceed in a direct line from a new point.

Thus, for instance, if it be decided to have no greater rate of inclination than 1 in 35, on a new line of road, from A to B (Plate I. Fig. 1.), and the surveyor, when he arrives at the point *a*, finds a greater inclination than this, he must incline from the direct line to *b*. Having then gained the summit of the hill, he does not endeavour to get back into the original straight line A B, but pursues the direct line *b* B, unless he is again obliged, from a similar cause, to deviate from it. This part of the survey being accomplished, it will then become necessary to examine the practicability of making a direct line of road, between A and *b*, instead of going to the point *a*.

When hills are high and numerous, it sometimes appears, from a perambulation and inspection of the country, to be advisable to leave the straight line altogether from the beginning, in order to cross the ridges, at lower levels, by a circuitous course, in the way represented by the dotted lines A *c d*, in the above figure.

It constantly happens that although inclinations which do not exceed the prescribed rate can be had without quitting the straight line, the ridges may be crossed, at many feet of less perpendicular height, by winding the road over lower points of

them; but the propriety of doing so will depend upon the length that a road will be increased by going round to avoid passing the ridges in the direct line. The saving of perpendicular height to be passed over by a road, though a matter of so much importance and practical utility, has not hitherto received that attention from engineers which it deserves. For this reason it has been deemed advisable to bestow much consideration on it; but, as the investigation requires minute and extensive details, and cannot be conducted with full effect, without having recourse to algebraical formulæ, it has been transferred and given in note A.

When expeditious travelling is the object. the maximum rate of inclination that never should be exceeded in passing over hills, if it be practicable to avoid exceeding it, is that which will afford every advantage in descending hills, as well as in ascending them. For, as carriages are necessarily retarded in ascending hills, however moderate their inclinations may be, if horses cannot be driven at a fast pace in going down them, a great loss of time is the result. This circumstance is particularly deserving of attention, because the present average fast rate of driving over any length of road can be accomplished in no other way than by going very fast down

the hills. But when the hills are very steep, and a coachman cannot keep his time except by driving very fast down them, he exposes the lives of his passengers to the greatest danger.

How much time is lost in descending steep hills will appear from the following statement: — Suppose a hill to be so steep as not to admit of a stage coach going faster down it than at the rate of six miles an hour, five minutes will be required for every half mile: but, if the hill were of an inclination of 1 in 35, it might be driven down with perfect safety at the rate of twelve miles an hour; at which rate the time for going half a mile would be two minutes and a half, so that there is a loss of half a mile in distance for every half mile down the steep hill.

Besides the loss arising from the additional horse-power required to draw over very steep hills, there are other circumstances which make it desirable to avoid them.

In descending them, the drag becomes indispensably necessary. In coach travelling, the stopping to put it on and take it off will be the loss of at least one furlong to a coach travelling at the rate of ten miles an hour; for in slacking the pace of the horses, and before they stop, nearly one minute will be occupied.

When coachmen, to save trouble, omit to put on the drag, or, as it sometimes happens, when it breaks, travellers are liable to the most dangerous description of accidents by the overturning of a coach when going at a great velocity. Even with the drag, heavy loaded carts are always taken by their drivers into the side channels of the road to try to check their speed; and thus the channels are cut into deep ruts, or rather troughs, and the under-drains broken in, unless strong posts of wood or stone are set up, which are unsightly, and dangerous to other carriages when descending at a quick rate.

An inclination of 1 in 35 is found by experience to be just such an inclination as admits of horses being driven in a stage coach with perfect safety, when descending in as fast a trot as they can go; because, in such a case, the coachman can preserve his command over them, and guide and stop them as he pleases. A practical illustration that this rate of inclination is not too great, may be seen on a part of the Holyhead Road, lately made by the Parliamentary Commissioners, on the north of the city of Coventry, where the inclinations are at this rate, and are found to present no difficulty to fast driving, either in ascending or descending. For this reason it may be taken as a general rule, in laying out a line of new road,

never, if possible, to have a greater inclination than that of 1 in 35. Particular circumstances may, no doubt, occur to require a deviation from this rule; but nothing except a clear case that the circuit to be made to gain the prescribed rate would be so great, as to require more horse labour in drawing over it, than in ascending a greater inclination, should be allowed to have any weight in favour of departing from this general rule. On any rate of inclination greater than 1 in 35, the labour of horses, in ascending hills, is very much increased. The experiments detailed in the Seventh Report of the Parliamentary Commissioners of the Holyhead Road, made by a newly invented machine for measuring the force of traction or power required to draw carriages over different roads, fully establish this fact.*

Hilly ground is not always to be avoided, as being unfit for a road; for, if the hills are steep and short, it will often be easier to obtain good inclinations, or even a level road, by cutting down the summits, and laying the materials taken from them in the hollow parts. But this must be regulated by the expense to be incurred, which is a main consideration, that should always be scrupulously attended to before an engineer

* See Appendix No. I. for a description of this machine.

decides upon the relative merit of several apparently favourable lines. A perfectly flat road is to be avoided, if it is not to be raised by embanking at least three or four feet above the general level of the land on each side of it, so as to expose the surface of it fully to the sun and wind; for if there is not a longitudinal inclination of at least 1 in 100 on a road, water will not run off; in consequence of which, the surface, by being for a longer time wet and damp than it otherwise would be, will wear rapidly away, and the expense of maintaining it in order by scraping it and laying on materials will be very much increased.

The great fault of all roads in hilly countries is, that, after they ascend for a considerable height, they constantly descend again before they gain the summit of the country which they have to traverse. In this way the number of feet actually ascended is increased many times more than is necessary if each height, when once gained, were not lost again.

As one instance, amongst others, of the serious injury which the public sustains by this system of road-making, the road between London and Barnet may be mentioned, on which the total number of perpendicular feet that a horse must now ascend is upwards of 1300, although

Barnet is only 500 feet higher than London: and, in going from Barnet to London, a horse must ascend nearly 800 feet, although London is 500 feet lower than Barnet.*

Another instance of this defect in road engineering is observable in the line of old road across the island of Anglesea, on which a horse was obliged to ascend and descend 1283 perpendicular feet more than was found necessary by Mr. Telford, when he laid out the present new line, as shown by the annexed table:—

	Height of summit above high water.	Total rise and fall.	Length.	
			Miles.	Yards.
Old Road	339	3540	24	428
New Road	193	2257	21	1596
Difference	146	1283	2	592

Another instance may be observed in the road from South Mimms to Barnet. The old

* In this case the Highgate and the Hampstead ridge makes it impossible to save the whole of these 800 feet without a great circuit; but several hundred feet might be saved by a proper improvement of the present road.

road ascends three rather steep and long hills, while the new road avoids, almost entirely, two of these hills, at the same time that it is shorter by 638 yards.

In tracing a road across a deep valley between two hills, it should be carried in a direction opposite to the fall of the valley, as by so carrying it, that is, by crossing the valley at the highest practicable point, the descent and ascent are diminished.

Thus, in going from A to B, across a valley, if it be found by levelling, that in a straight line the valley is too deep to make an embankment at a reasonable expense, the surveyor should try a line, A C B, higher up the valley, rather than in the direction A D B, where he would get into a lower level, (see Plate I. Fig 2.) Although this is the general principle, instances may occur, where a valley may be crossed with more advantage down stream; as, for instance, if the sides of a valley contract considerably, it may require much less embankment to raise the road to the same height, than if it were carried higher up the valley; see Plate I. Fig. 3., by which it appears that it would be more advisable to take the line A D B, than either the straight line A B, or the line A C B, higher up the valley.

Another instance where a valley may be crossed with more advantage down stream, is where detached or insulated hills are situated in the valley below the straight line of direction, as represented in Plate I. Fig. 4. Here it would be proper to pass the valley lower down, to take advantage of the intervening high ground, as will be seen by the section, in which it is evident that much less embankment will be required in the line A D B, than in either the direct line A *b* B, or the line A *c* B, higher up the valley. Lately, when it was proposed by the Parliamentary Commissioners of the Holyhead Road, to improve the valley of the Geese Bridge, between Towcester and Daventry, on the road from London to Birmingham, six different surveys and plans of doing so were made. The report on these surveys is given in note A, more fully to explain the rules for crossing valleys. In many situations, particularly in mountainous countries, it will be found necessary to pass valleys or deep ravines by means of high arches of masonry, as in some parts of Scotland, where Mr. Telford has erected several great works of this description; of these, the most remarkable are the bridges over the Mouse Water, at Cartland Craigs, on the Lanark Road, represented in Plate I. Fig. 5. The bridge over Birkwood Burn, near Lesmahago, on the Glasgow

Road, represented in Plate I. Fig. 6., and the Fidlor Burn Bridge, on the Lanark Road, represented in Plate I. Fig. 7.*

The suspension bridge over the Menai Straits, in North Wales, is of a similar character, for, besides its use in passing these straits, it has improved the road by its being no longer necessary to descend to the level of the water. See Plate I. Fig. 8.

In most cases, however, valleys may be crossed by high embankments of earth, such as the chalk hill embankment near Dunstable, and that near Chirk, in North Wales.

In some situations it may be advisable to pass through a hill by means of a tunnel, instead of by deep cutting.

There are three works of this kind on the Simplon Road. One of them, "*la grande galerie de Gondo,*" is 240 yards in length, 8½ in breadth, and the same in height.† There is a similar

* To this list may be added the Dean Bridge over the Water of Leith at Edinburgh, which is above 100 feet high, and consists of four arches of 90 feet span; and a bridge at Pathhead, on the Coldstream road of five arches of 80 feet span.

† It would appear from the following extract from a Memoir of M. Ceard, on the Simplon Road, that some great errors were made in laying out the line of this famous road.

work at Puzzuoli, near Naples, which is nearly half a league long; it is fifteen feet broad and as many high.

M. Ceard was the chief engineer, and claims the merit of being the author of the plan.

FIRST BRIGADE.

Troop of M. C——.

The plan of the road, once adopted, it became the duty of the head engineers, and more especially of the younger officers under their command, strictly to follow what had been decided upon. M. C——, and the engineer with whom he acted, entertained, however, a different opinion, and exercised their discretion. After much labour was uselessly expended by them in attempts which they were obliged to abandon, the first ascent, which should have been an uniform inclined plane, rising regularly six inches in seventy-two, on the side of the mountain of Brandevald, was constructed in an irregular manner, the incline rising sometimes seven inches in seventy-two, sometimes eight, sometimes three, or less, and sometimes nothing. This error was committed in my absence, and when I discovered it, too much labour and money were expended, to abandon what had been executed, without considerable loss; besides which, the government would have been exposed to the public ridicule, which would be excited by the exposure of the blunders of those employed by it. Such was the first consequence of M. C——'s mismanagement in this ascent.

The second division of the road was arranged to proceed from the first summit to the bottom of the valley of Ganther. This was to have been effected by an inclined plane, at the rate of two inches in seventy-two; but the course followed by these engineers doubled this rate; and if I had not interrupted their departure from the original plan, the road would

RIVERS.

The peculiar circumstances of a river may render it necessary to deviate from a direct line in laying out a road.

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have been carried across three torrents, over which bridges must have been thrown, in situations almost inaccessible, and exposed to destruction by avalanches, instead of a single bridge, which alone was necessary by the original plan, situated also in a position free from those objections.

The consequences of this second error in arranging the inclinations of the road were, that it was necessary to elevate the line of the road, (in order to avoid the inconvenience of having to make a descent and then an ascent,) and to give double the necessary height to the bridge of Ganther, the position of which admitted of no change. It was necessary also to increase the height of the stone buttresses of the bridge, to the extent of at least twenty metres (sixty-five feet), to supply the place of the support which would otherwise have been derived from natural rocks; and finally, to construct considerable causeways, and to make the carpentry of the bridge of that height which the torrent required. Such were the consequences of M. C——'s proceedings.

I shall continue to investigate the labours of this young engineer.

Having to superintend, besides the Simplon road, fifty leagues of road in Italy, in the Valais, in Savoy, and upon Mount Jura, I could not be always present at the Simplon to watch the proceedings of these gentlemen; but I trusted that the superintending engineer, C——, satisfied with the consequences of his first departure from the plan laid down by the council, would follow, for the future, implicitly the

A difficulty may arise from the breadth of the river requiring a bridge of extraordinary dimensions, or from the land for a considerable distance on the sides of the river being subject to be covered with water to the depth of several feet in floods.

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directions given to him. I was, however, deceived in this expectation.

The plan prescribed by the council did not permit, in the ascent from the bridge of Ganther to the summit of the Simplon, any inclination exceeding five inches in seventy-two. M. C——, however, caused to be constructed three pieces of road, in a zig-zag form, which, while they increased the length of the road to the extent of 2169 yards, far from moderating its acclivity, occasionally increased it, a serious error in works of this nature. He acted in this case on his own responsibility; relying, perhaps, on that of his chief of brigade. As a consequence, it became necessary to mount and traverse some difficult ground, to form enormous excavations, worse than useless, because dangerous from the snow which would collect in them, a circumstance most to be avoided, and to carry the level of the road under the glaciers; all consequences of the original error committed at the base, in having ascended too rapidly, instead of having ascended by one regular inclined plane, rising five inches in seventy-two, as had been decided on in the original plan, and thus reaching the summit of the Simplon and the Hospice, by the course at once the most gentle in its ascent, and the noblest in its length. This piece of work, on which about 300,000 francs had been squandered, is likewise due to M. C——, who in two leagues and a half of road has committed, as we have seen, several serious blunders, in spite of all my efforts to oppose him.

In these cases it may appear, upon accurately calculating and balancing the relative inconvenience and expense of endeavouring to keep a straight line and of taking a circuitous route, that upon principles of security, convenience, and expense, the circuitous course will be the best.

In general, rivers have been allowed to divert the direct line of a road too readily. There has been too much timidity about incurring the expense of new bridges, and about making embankments over flat land to raise the roads above the level of high floods.

These apprehensions would frequently be laid aside, if proper opinions were formed of the advantages that arise from making roads in the first instance, in the shortest directions, and in the most perfect manner. If a mile, half a mile, or even a quarter of a mile of road be saved, by expending even several thousand pounds, the good done extends to posterity, and the saving that will be the result in annual repairs and horse labour, will, before long, pay off the original cost of the improvement.

BOGS AND MARSH GROUND.

The elastic nature of all bogs and marshes, and of all boggy and bottom land, makes it im-

possible to form a road of perfect hardness over a soil of this kind, unless a great deal of labour and expense is applied in draining the soil, and afterwards compressing it, by loading it with large quantities of earth embanked upon it, in order to destroy the elasticity of the subsoil.

Although the surface coating of a road over such a subsoil may be made with a great abundance of the hardest materials, and be perfectly smooth, the porous and moist texture of the subsoil will cause the road to yield to a carriage passing over it; and thus, by destroying the momentum of it, add greatly to the labour of the horses in drawing it.*

For this reason it will generally be prudent to deviate from the direct line in laying out a new road, if by doing so this sort of subsoil can be avoided, without adding much to the length of it. But when the additional length of the road would be considerable, it will then be necessary to incur the expense of a proper drainage, and of forming so high an embankment, as to compress and harden by its weight the moist and porous subsoil. Such an embankment, of 1740 yards in length, having this object in view, was

* The reference which will be made to the laws of motion in a subsequent chapter, will show how extremely injurious elasticity is in increasing the labour of horses.

made over Maldreath Marsh, in the Island of Anglesea, on the new line of the Holyhead Road.

MATERIALS.

It will sometimes happen that road materials can be better obtained by carrying a line of road in one direction than in another. This will be a good reason for making a road deviate from the direct line, because the expense of making and repairing it will much depend on the distance which materials have to be carried.

EXPOSURE.

It is necessary, in making a road through a hilly country, to take particular care to give it a proper aspect. It is a great advantage to have a road on the north side of a valley fully exposed to the sun. For the same reason, all woods, high banks, high walls, and old fences ought to be avoided, in order that the united action of the sun and wind may have full power to produce the most rapid evaporation of all moisture. Too much attention cannot be bestowed on this object, in consequence of the effect of water in contributing to cut and wear down the hardest substances. It is for this reason that road materials, when they are wet or damp, wear rapidly

away under the weight and pressure of heavy carriages. The hardest limestones wear away very quickly when wet, and all stones of an aluminous character, and also gravel that consists of flint, sandstone, or other weak pebbles.

The great advantage of having a road perfectly exposed to the action of the sun and wind, will be more accurately conceived, by referring to writers of science on evaporation. Dr. Halley states, that one tenth of an inch of the surface of the sea is raised per diem in vapour. He also says, that the winds lick up the water somewhat faster than it exhales by the heat of the sun. Other writers say, the dissipation of moisture is much accelerated by the agency of sweeping winds, the effects being sometimes augmented five to ten times.

Trees are particularly injurious, by not allowing the sun and wind to have free action on the surface of roads in producing evaporation. Besides the benefit which a road receives from its drying rapidly, by an open exposure to the atmosphere, there is another of great importance, namely, that of affording to horses the advantage of free respiration; for it is well known that the powers of a horse to perform work with ease, particularly when moving rapidly, depends upon the quantity of cool and fresh air that he can pass through his lungs. If the cause of

horses tiring or becoming ill under their work be carefully examined into, it will often be found that it is not their muscles or limbs that fail them, but their wind; and therefore it is particularly important to have a road so circumstanced, that a horse may, on all parts of it, have the benefit of a free current of air.

It may sometimes be proper to make a road deviate from a straight line, in order to go through a town; but the expediency of such a deviation must wholly depend on the general object of the road. If it be intended to expedite the communication between two places of great trade, or otherwise of great importance, then nothing can be more erroneous than allowing the general line of road to be taken from the best and shortest direction in order to pass through a town. It is for this reason that little attention should be paid to the opposition of inhabitants of towns to new roads, when to be made for the advantage of the general communication of distant and important parts of the kingdom.

Some persons may be disposed to say, that a road should be made to deviate from a direct line in order to avoid crossing parks, or demesnes, and, to a certain extent, no doubt it should; but this motive ought not to be allowed to have much weight, where the consequence is to force the road over an inconvenient ascent, or

to add very materially to its length. It should be recollected, that, by judicious management, a road may be made, if not ornamental, at least not injurious or detrimental to the appearance or privacy of a park, by carrying it in hollow ground, or between sunk fences.

The principle of protection of private property is itself founded on the same principle that should govern the line of a road, and that principle is the public advantage; and therefore it should be laid down and acted upon as a general maxim, that private considerations ought in all cases to be made to give way, with respect to roads, to public convenience. "For let it be remembered that society is formed for the mutual and general benefit of the whole; and it would be a very unjust measure to incommode the whole merely for the convenience, or perhaps the gratifying of the whim or caprice of an individual."*

After fixing upon a general line of a road with respect to its direction, the precise line of it must be marked out, according to the smaller acclivities and declivities of the natural surface of the country it is to pass over. As moderate curves add but little to the length of a road, they will not be objectionable, if they assist the inclinations and save expense.

* Bateman on Roads, p. 122.

CHAP. II.

PRINCIPLES OF ROAD-MAKING.

In this chapter, the general principles will be examined, according to which the art of constructing a road should be practised; and the particular methods will be explained, by which various kinds of roads should be constructed. The art of road-making, like every other art, must essentially depend for its being successfully conducted on its being exercised in conformity with certain general principles, and the justness of these principles should be rendered so clear and self-evident as not to admit of any controversy.*

* "A knowledge of true principles is indispensably necessary in every art, and in that of making roads as much as in any other. Some preliminary species of knowledge is very necessary in every superintendant or surveyor. A beaten track of knowledge is but a bad guide in cases which very frequently occur, when, amongst several ways, the best is to be preferred."—*M. S. Haldimand*, Secretary to the Bailiwick of Yverdun, on the Construction of Highways.

One of the most important and most obviously correct of these principles, is that which requires a road to be made of such a degree of substance, as shall be in a due proportion to the weight and number of the carriages that are to travel over it.

But although this is, in appearance, a self-evident proposition, in practice no rule is so universally violated.

Let the construction of any turnpike road, of one commonly considered as among the best, be properly examined; that is, let measure be taken of the quantity of hard-road materials that compose the crust of the road over the subsoil, and it will almost universally be found that it consists of only from three to five, or six inches in thickness.* Whereas, instead of this weak and defective system of road-

* See Mr. Telford's first Annual Report on the Holyhead Road, in 1823, where tables are given showing the result of trials made along the whole line of road from London to Shrewsbury of the depth of materials, by sinking holes into the road at short intervals. The average depth of materials was as follows on some of the trusts:—

Whetstone	Trust	4	inches.
St. Alban's	ditto	4	ditto.
Dunstable	ditto	4¼	ditto.
Puddle Hill	ditto	3¾	ditto.

making, it may be laid down as a general rule, that on every main road where numerous heavy waggons and heavy loaded stage coaches are constantly travelling, the proper degree of strength which such a road ought to have cannot be obtained except by forming a regular foundation constructed with large stones, set as a rough pavement, with a coating of at least six inches of broken stone of the hardest kind laid upon it; and further, that in all cases where the subsoil is elastic, it is necessary, before the foundation is laid on, that this elastic subsoil should be rendered non-elastic by every sort of contrivance; such, amongst others, for instance, as perfect drainage, and laying a high embankment of earth upon the elastic soil, to compress it.

The right understanding of this principle of road-making, which requires roads to be constructed with four or five times a greater body or depth of materials than is commonly given to them, is of such great importance, that it is requisite to illustrate and establish the grounds on which it rests; first, by reference to the laws of science concerning moving bodies, and secondly, by reference to experiments, which accurately prove the force of traction on different kinds of roads.

As a carriage for conveying goods or pas-

sengers when put in action becomes a moving body, in the language of science, the question to be examined and decided is, how a carriage, when once propelled, can be kept moving onwards with the least possible quantity of labour to horses, or of force of traction?

Sir Isaac Newton has laid it down as a general principle of science, that a body, when once set in motion, will continue to move uniformly forward in a straight line by its momentum, until it be stopped by the action of some external force. This proposition is admitted and adopted by all natural philosophers as being perfectly true, and therefore, in order to apply it to roads, it is necessary to enquire what kinds of external force act in a manner to diminish and destroy the momentum of carriages passing over them. With respect to these external forces, the general doctrine is, that they consist of 1st, collision; 2d, friction; 3d, gravity; and 4th, air.*

1st, The effect of collision is very great in diminishing the momentum of carriages; it is occasioned by and is in proportion to the hard protuberances and other inequalities on the surface of a road. These occasion, by the resistance which they make to the wheels, jolts and shocks,

* See Wood's Mechanics, p. 20.

which waste the power of draught, and considerably check the forward motion of a carriage.

The mathematical illustration of the effect of collision in producing this resistance is given in note B.

2d, Friction has a very great influence in checking the motion of a carriage; for, when the wheels come into contact with a soft or elastic surface, the friction which takes place operates powerfully in obstructing the tendency of the carriage to proceed; the motion forwards is immediately retarded, and would soon cease if not renewed by the efforts of the horses. The "resistance," Professor Leslie says, "which friction occasions, partakes of the nature of the resistance of fluids; it consists of the consumption of the moving force, or of the horse's labour, occasioned by the soft surface of the road, and *the continually depressing of the spongy and elastic substrata of the road.*" *

An ivory ball, set in motion with a certain velocity over a Turkey carpet, will suffer a visible relaxation of its course; but, with the same impelling force, it will advance further if rolled over a superfine cloth; still further over

* Elements of Natural Philosophy.

smooth oaken planks; and it will scarcely seem to abate its velocity over a sheet of pure ice.

This short explanation of the nature and effects of collision and friction is sufficient to show, that smoothness and hardness are the chief qualities to be secured in constructing a road. But perfect smoothness cannot be obtained without first securing perfect hardness, and therefore the business of making a good road may be said to resolve itself into that of securing perfect hardness.

With the view of taking the right course for securing this object, the first thing a road trustee or engineer should do, is to form a correct notion of what hardness is; because the common habit of overlooking this circumstance has been the source of great error in forming opinions upon the qualities of different kinds of roads.

Gravel roads, for instance, to which an appearance of smoothness is given by incurring a vast expense in scraping them, and patching them with thin layers of very small gravel, are very commonly declared to be perfect, and unequalled by any other kind of road. But if the best gravel road be compared with one properly constructed with stone materials, the hardness of the former will be found to be greatly inferior to

that of the latter, and the error of the advocates of smooth-looking gravel roads will be immediately made manifest.

By referring to works of science, it will be seen that hardness is defined to be that property of a body by which it resists the impression of other bodies which impinge upon it; and the degree of hardness is measured by the quantity of this resistance. If the resistance be so complete as to render it totally incapable of any impression, then a body is said to be perfectly hard.*

Now this hardness is the hardness which a road ought to have as far as it is practicable to produce it, and it is the chief business of a scientific road maker to do every thing necessary to produce it. For this purpose, when making a new road, he should first select or establish a substratum of soil or earth that is not spongy or elastic, for the bed of the road; and then he should so dispose the materials of which the crust of the road is to consist, as to form a body sufficiently strong to oppose the greatest possible quantity of resistance to the weight of heavy carriages passing over it.

* Bridges' Natural Philosophy, vol. i. p. 150.

That an elastic subsoil is unfit for a road is evident from the nature of the resistance occasioned by friction, as above described by Professor Leslie, and from the terms of the definition of hardness; for however strong the crust of materials may be which is formed over such a subsoil, it will not be capable of opposing a perfect resistance to a heavy moving body. The moving body will sink more or less in proportion as the subsoil is elastic, and the hardness of the road will be imperfect in proportion as this sinking takes place; so that nothing can be more necessary, as a preliminary step in making a new road, than to take every possible precaution to avoid elastic subsoils, or to destroy the elasticity as much as possible, when no other can be found.

After the engineer has prepared a proper substratum of earth for the bed of a road, he next must construct a crust of road materials in such a manner that, when consolidated, it shall possess such a degree of hardness as will not admit the wheels of carriages to sink or cut into it. For this purpose it will not be sufficient to lay upon the prepared bed of earth merely a coating of broken stones, for the carriages passing over them will force those next the earth into it,

and, at the same time, press much of the earth upwards between the stones; this will take place to a great degree in wet weather, when the bed of earth will be converted into soft mud by water passing from the surface of the road, through the broken stones, into the bed of the road. In this way a considerable quantity of earth will be mixed with the stone materials laid on for forming the crust of the road, and this mixture will make it extremely imperfect as to hardness. It might be possible, in some measure, to cure this defect by laying on a succession of coatings of broken stones; but several of these will be necessary, and, after all, in long continued wet weather, the mud will continue to be pressed upwards from the bottom to the surface of the stones. If even a coating of from sixteen to twenty inches of stones be laid on, it will produce only a palliative of the evil. So that this plan of making a road will be not only very imperfect, but at the same time very expensive.

Mr. Telford's plan, which has completely succeeded on the Holyhead Road, the Glasgow and Carlisle Road, and several other roads in Scotland, of making a regular bottoming of rough, close-set pavement, is a plan that secures the greatest

degree of hardness that can be given to a road; it is also attended with much less expense than when a thick coating of broken stones is used; for six inches of broken stones is sufficient when laid on a pavement, and the pavement may be made with any kind of common stone.

By laying the stones in making the bottoming with their broadest face downwards, and filling up the interstices closely with stone chips well driven in, the earthy bed of the road cannot be pressed up so as to be mixed with the coating of broken stones. This coating, therefore, when consolidated, will form a solid uniform mass of stone, and be infinitely harder than one of broken stones, when mixed with the earth of the substratum of the road. It is by proceeding in the way here recommended that the friction of wheels on a road will be reduced as much as possible.*

To comprehend thoroughly the great importance of making a regular and strong foundation for a road, it should be borne in mind, that roads are structures that have to sustain great weights, and violent percussion; the same rules therefore ought to be followed in regard to them as are followed in regard to other structures.

* The mathematical illustration of the effect of friction on carriages is given in note C.

In building edifices which are to support great weights, whether a church, a house, or a bridge, the primary and indispensable consideration of the architect is to obtain a permanently firm and stable foundation; well knowing that unless this be first substantially made, no future dependence can be placed on the stability of the intended superstructure: but this most requisite precaution has but recently been attended to in the formation of roads, and only on those roads in Scotland, and between London and Holyhead, which have been under the direction of Mr. Telford.

If the foundation of a road be not sufficient and equal to the pressure it has to sustain, the whole fabric, though in other respects ever so well constructed, must fail in permanent stability, and the hardness of it will be imperfect from its elasticity.

Having now stated all that the rules of science relating to moving bodies suggest, in order to defend the principles of road making, which have been laid down as the proper principles to be adopted, we shall now proceed further to illustrate and support these principles, by referring to experiments of the force of traction on different kinds of roads. These experiments have

been made with the machine invented by Mr. Macneill, which has been already mentioned, and may be relied upon for their accuracy, in consequence of their having been carefully examined by several very eminent civil engineers.

These experiments uniformly show, that the force of traction is, in every case, nearly in an exact proportion to the strength and hardness of a road. The following are the results: on a well-made pavement, the power required to draw a waggon is 33 lbs.; on a road made with six inches of broken stone of great hardness, laid on a foundation of large stones, set in the form of a pavement, the power required is 46 lbs.; on a road made with a thick coating of broken stone, laid on earth, the power required is 65 lbs.; and on a road made with a thick coating of gravel, laid on earth, the power required is 147 lbs.* Thus it appears that the results of actual experiments fully correspond with those deduced from the laws of science.

It has been considered necessary to enter into these details in showing that no road can be correctly called a good road unless it is so constructed as to be a very strong and a very hard one, be-

* See Appendix, No. I.

cause all the main roads of the kingdom are still very defective in respect to strength and hardness. This is a fact which cannot be disputed; first, because there is always mixed up with the body of materials, which forms the crust of every road, a great quantity of earth; secondly, because this crust is every where too thin; and, thirdly, because it very frequently lies upon an elastic substratum. Although there may be exceptions, this may be taken as an accurate description of the general state of the roads.

Notwithstanding all the roads are now much better than at any former period, and may deserve to be called good roads, in comparison with the roads of ten or fifteen years ago; when it is considered how much better they would be if they were reconstructed with a proper foundation coated with broken stones of great hardness, they should still be set down as being imperfect roads. Let any road trustee or surveyor who doubts this, reconstruct a mile of a road, now considered an excellent one, with a bottoming of pavement, coated with hard stones, and no stage coachman who shall drive over it will hesitate to bear testimony to the increased ease with which his horses do their work upon it.

The explanation which has been given in this chapter of the laws of motion, as applicable to the subject of road making, and particularly of the effect of an elastic substratum of a road, as stated by Professor Leslie, in consuming the moving force, and adding to the horse's labour, is quite conclusive in showing how much at variance to the first principles of science the following doctrines are, which are to be found in some modern publications.

"That a foundation or bottoming of large stones is unnecessary and injurious on any kind of subsoil."

"That the maximum strength or depth of metal requisite for any road, is only ten inches."

"That the duration only, and not the condition of a road, depends upon the quality and nature of the material used."

"That free stone will make as good a road as any other kind of stone."

"That it is no matter whether the substratum be soft or hard." *

* The passages marked with inverted commas have been extracted from the publications of Mr. M'Adam.

As many persons advocate Mr. M'Adam's doctrine of elastic roads, it may serve to show the real value of it,

Mr. Wingrove, an eminent practical road surveyor, observes, in a Treatise on the Bath roads, after quoting these sentences, "that with

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by putting it in juxta-position with that of the celebrated natural philosopher, the late Professor Leslie.

Extract from the Evidence of Mr. M'Adam. (Remarks on Road-Making, p. 111.)	*Extract from Professor Leslie's "Elements of Natural Philosophy."*
"What depth of solid materials would you think it right to put upon a road in order to repair it properly?—I should think that ten inches of well consolidated materials is equal to carry any thing. "That is, provided the substratum is sound?—No: I should not care whether the substratum was soft or hard: I should rather prefer a soft one to a hard one. "You don't mean to say you would prefer a bog?—If it was not such a bog as would not allow a man to walk over, I should prefer it. "But must not the draught of a carriage be much greater on a road which has a very soft foundation than on one which is of a rocky foundation?—I think the difference would be very little indeed, because the yield of a good road on a soft foundation is not perceptible."	"The resistance which friction occasions (to carriages) partakes of the nature of the resistance of fluids: it consists of the consumption of the moving force, or of the horse's labour, occasioned by the soft surface of the road, and *the continually depressing of the spongy and elastic substrata of the road.*"

respect to these opinions on road-making, nothing but the complete ignorance of the public, upon all matters concerning road-making, could ever have suffered rules, so contrary to every thing like sound principles, to have had a single moment of favourable consideration."*

3d, The resistance produced by gravity, in checking the progress of a moving body on a road, is little or nothing when a road is horizontal, because as gravity acts in a direction perpendicular to the plane of the horizon, it neither accelerates nor retards the motion.† But when the road is not horizontal, the power of gravity is a great impediment.

A mathematical illustration of the effect of gravity on hills is given in note D.

4th, The resistance arising from the action of the air is very variable; in some cases, it acts powerfully; but as its influence is the same

* Mr. Wingrove was for several years the surveyor of nearly all the roads in the neighbourhood of Bath. In 1825 the author accompanied him in making an inspection of them, and found the rules which Mr. Telford recommends had been most effectually acted upon throughout the whole of these roads, and that they had been brought to as high a state of improvement as the money which was allowed for them would admit of.

† Wood's Mechanics, p. 20.

whether the road be a bad or a good one, little need be here said on the subject: it will be sufficient to state, that by experiments detailed in Smeaton's Reports, it was found that the force of the wind on a surface 1 foot square was 1 lb., when the velocity of the wind was 15 miles an hour, or what would be termed a brisk gale; 3 lbs. when the velocity was 25 miles an hour, or what would be termed a very brisk gale; 6 lbs. when the velocity was 35 miles per hour, or what might be termed a high wind; and 12 lbs. to the square foot, when the velocity was 50 miles an hour, or what might be termed a storm. Supposing, therefore, that the surface of that part of a carriage acted upon by the direct influence of the wind to be 50 superficial feet, the resistance it will meet from a brisk gale of wind acting against it will be about 50 lbs. when the carriage is slowly moved; but if the carriage be supposed to move directly against the wind with a velocity of 10 miles an hour, and the wind to move with a velocity of 15 miles an hour, the resistance against the carriage will amount to 3 lbs. on the square foot, or 150 lbs. on the carriage, which is fully equal to the power which two horses should be required to exert, when moving with a velocity of 10 miles an

hour. From this the difficulty is evident of driving stage coaches at a rapid rate against high winds.*

* The proper angle for fixing the line of direction of traces, in which the power for drawing a carriage should be applied, is described in note F.

CHAP. III.

FORMING A ROAD.

In marking out the line of a road, a great deal of expense in cutting and embanking for forming the bed on which the road materials are to be placed, may be avoided by a judicious selection of the high and low ground which the surface of the country affords.

The chief care, where a road must be carried over a high elevation, is to lay it out so that it shall not have any fall in it from the point from which it departs till it reaches the summit. The lowering of heights, and the filling of hollows, should be so adjusted as to secure gradual and continued ascending inclinations to the highest point to be passed over.

It is a most important part of the business of a skilful engineer to lay out the longitudinal inclinations of a road with the least quantity of cutting and embanking.

He must do this by measuring and calculating the quantity of earth to be removed in

cuttings, and taking care that it shall exactly make the embankments for raising the hollows to the required heights; a proper allowance being made for the subsidence of the soil according to its quality, without leaving an overplus to be carried to spoil.*

When it is necessary to make a deep cutting through a hill, the slopes of the banks should never be less, except in passing through stone, than two feet horizontal to one foot perpendicular; for though several kinds of earth will stand at steeper inclinations, a slope of two to one is necessary for admitting the sun and wind to reach the road. The whole of the green sod and fertile soil on the surface of the land cut through should be carefully collected and reserved, in order to be laid on the slopes immediately after they are formed.

If a sufficient quantity of sods cannot be procured in the space required for the road, the slopes should be covered with three or four inches of the surface mould, and hay seeds should be sown on it; by this plan the slopes will soon be covered with grass, which will be a great means of preventing them from slipping.

When stones can be got the slopes should be

* See Mr. Macneill's Work on Cutting and Embanking. Published by Roake and Varty.

supported by a wall raised two or three feet high at the bottom of them. These walls prevent the earth from falling from the slopes into the side channels of the road, and add very much to the finished and workmanlike appearance of a road.

In many cases it may be advisable, particularly if an additional quantity of earth be wanted for an embankment, to make the slopes through the cuttings on the south side of a road of an inclination of three horizontal to one perpendicular, in order to secure the great advantage of allowing the sun and wind to reach more freely the surface of the road.

In districts of country where stones abound, expense in moving earth and purchasing land may be avoided, by building retaining walls, and filling between them with earth. In rocky and rugged countries this is generally the best way of obtaining the prescribed inclinations.

In forming a road along the face of a precipice, a wall must be built to support it. The difficulty of forming a road in such a place is not so great as is imagined, for the face of a precipice is seldom perpendicular, and if the inclination should be half a foot perpendicular to one foot horizontal, this will admit of a retaining wall being built.

By building such a wall, say thirty feet high, and cutting ten feet at that height into the rock, and filling up the space within the wall, a road of sufficient breadth will be obtained, as shown in Plate II. fig. 1.

In forming a road along the face of a hill that is indented with ravines, in place of carrying the road over the natural surface of the land, the projecting points should be cut through and the earth laid across the hollows so as to straighten the line, as shown in Plate II. fig. 2., where the road, instead of following the sinuosities of the hill, as represented by the dotted line *a a a*, takes the line *b b b*.

In forming the bed for the road materials care should be taken, except where cutting into the surface is wholly unavoidable in order to obtain the proper longitudinal inclinations, to elevate the bed with earth, two feet at least, above the natural surface of the adjoining ground: by following this course the road will not be affected by water running under or soaking into it from the adjoining land. In arranging the inclinations, they should be obtained by embanking, when that is practicable, in preference to cutting.

Almost all old roads across flat and wet land are sunk below the adjacent fields: this has arisen

from the continued wearing of them, and carrying away the mud. No improvement is more generally wanting than new forming these roads so as to raise their surfaces above the level of the adjoining land. This would greatly contribute to the hardness of them, to economy in keeping them in repair, and to enabling horses to work with the advantage of having sufficient air for respiration.

EMBANKMENTS.

Great care is necessary to be taken in making high embankments. No person should be intrusted with these works who has not had considerable experience as a canal or road maker; for, if the base of an embankment be not formed at first to its full breadth, and if the earth be not laid on in regular layers or courses of not exceeding four feet in thickness, it is almost certain to slip. In forming high embankments the earth should be laid on in concave courses, as represented in Plate II. fig. 3., in order to give firmness and stability to the work. It is not at all uncommon in many parts of the country to see embankments formed convexly, as represented in Plate II. fig. 4., the consequence of which is, that they are for ever slipping.

There have been but few attempts to make embankments by turnpike trustees that do not afford illustrations of this defect, and of a want of knowledge of the proper rules by which these works should be managed. No doubt, a chief reason for making cuttings and embankments, as is frequently the case, with slopes of one to one, has been, to save expense in the purchase of land, and moving earth. But the consequence of making such slopes, is that the earth is constantly slipping; so that, in the end, the expense is always greater in correcting the original error, than it would have been if proper slopes had been made in the first instance.

In forming embankments along the sides of hills, or what is called side-forming, the rule that should be followed, is that the slope to be covered should be cut into level steps to receive the earth, otherwise it will be very liable to slip down the hill: in such cases, the earth should be well compressed, and great care should be taken to intercept all the land springs about it by proper drainage. For this purpose, a drain should be cut on the upper side of the road, and open drains should be made on the side of the hill above the road, to catch the surface water of the hill.

The figure 5. in Plate II. explains the man-

ner in which the ground should be formed for side embankments, by cutting the level steps *a a a*, and shows where the drains should be made.

The slopes at which cuttings and embankments can be safely made entirely depend upon the nature of the soil. In the London and plastic clay formations, it will not be safe to make the slopes of embankments or cuttings, that exceed four feet high, with a steeper slope than three feet horizontal for one foot perpendicular. In cuttings in chalk or chalk marl, the slopes will stand at one to one. In sandstone, if it be solid, hard, and uniform, the slopes will stand at a quarter to one, or nearly perpendicular.

If a sandstone stratum alternate with one of clay or marl, as represented in Plate II. fig. 6., it is difficult to say at what rate of inclination the slopes will stand; this will, in fact, depend upon the inclination of the strata. If the line of the road is parallel to the line of the bearing of the strata*, in such cases, large masses of the

* The line of intersection of any inclined stratum with the horizontal plane, is called the line of bearing of that stratum, or the drift-line. The dip, or inclination, of the stratum is the angle formed between a horizontal plane and a line drawn at right angles to the drift-line on the bed of the stratum.

stone become detached, and slip down over the smooth and glassy surface of the subjacent bed. There are many instances of slips in sandstone and marl strata, under such circumstances as those now described, where the slopes are as much as four to one. If the road is across such strata, or at right angles to the line of bearing, then the slopes may be made one and a half to one, as represented in Plate II. fig. 7.; but if the strata lie horizontal, even though there should be thin layers of marl between the beds of stone, as in Plate II. fig. 8., the slopes will stand at a quarter to one. But it will be necessary, if the beds of marl exceed twelve inches in thickness, to face them with stone.

In the Oxford clay, which covers so great a portion of the midland counties of England, the slopes should not be less in any instance than two to one, and even in some parts of this formation they should be made three to one, if the cuttings be deep. In all such cases, if there be any beds of gravel or sand found intermixed with the clay, as shown in Plate II. fig. 9., drains should be cut along the top, and even in the sides of the cuttings; for, if this precaution be not taken, the water, which will find its way into the gravel, will, by its hydrostatic pressure,

force the body of clay down before it, and slips will take place even when the inclinations are as much as four to one; and, when this occurs, it is extremely difficult to re-establish them.

In limestone strata, if they be solid, slopes will stand at a quarter to one; but in most cases limestone is found mixed with clay beds, and in such cases the slopes should be one and a half or two to one. In the primitive strata, such as granite, slate, or gneiss, slopes will stand at a quarter to one.

Before quitting this subject, it is proper to remark, that in every instance of deep cutting, the greatest pains should be bestowed in examining the character of the material to be removed; much difficulty will be avoided by proceeding in this way: but, on the whole, the best general rule to follow, is always to lay out a line of road, so as to avoid as much as possible deep cuttings and high embankments; they are always attended with great expense, and are unavoidably liable to many objections.

The footpaths of a road should be formed at the same time as the bed of the road; also the fences, if they consist of mounds of earth or ditches: but these will be more particularly described in a subsequent chapter.

The following directions for forming roads

are taken from specifications according to which parts of the Holyhead road have been made.

First Specification.

"The black line on the section represents the natural surface of the ground, in the longitudinal direction of the new line, at about the middle of the space to be occupied by the road. The red line represents the proposed finished longitudinal surface of the bed, or what the road materials are to be laid upon; the red figures denote the depths of cuttings and the heights of the embankments, and also the rates of the inclinations: these rates of acclivity are to be strictly adhered to, and it is expressly stipulated that the contractor is to satisfy himself by his own measurement, or in any way he may think proper, as to the heights and depths, or any irregularities, of other parts of the surface of the ground to be cut down or embanked, or where there is to be side-cutting and forming, as no future claim on any pretence whatever will be allowed.

"The breadth of the finished road is to be thirty-six feet; viz. thirty feet for the carriage way, and six feet for the footpath. The slopes of all embankments from the outside of the quick

borders are to be two horizontal to one perpendicular, neatly dressed and covered with green sod at least four inches thick, evenly laid, and closely jointed.

"The slopes of the cuttings on the southern sides are to be three horizontal to one perpendicular; and those of the northern side to be two horizontal to one perpendicular: these slopes are to be correctly formed, neatly dressed, and covered with a good vegetable sod, the green side placed uppermost, and neatly jointed, and evenly laid, and to be at least four inches thick.

"The surface of the bed for the materials of the carriage way is to be formed level from side to side, the breadth between the bottom of the side slopes in the cuttings at the level of the bottom of the road materials is to be thirty-one feet.

"The surface of the bed for the hard materials of the footpath is also to be level, and to be seven inches above that of the carriage road. The necessary breadth will be gained by the road materials resting on the sides of the slopes.

"Where there is to be cutting in the side of a hill, the slope of the bank is to be two horizontal to one perpendicular: the embankment is to be secured by cutting the slope of the hill below the line of road into level steps to receive the earth,

and the road materials are not to be laid on the embankment until the inspector is satisfied it will stand."

Second Specification.

"In each of these lots the contractors are to make the line of the road agreeably to the plans and longitudinal sections made out and signed by Mr. Telford, as laid out upon the ground by him, or such person as he shall appoint. The breadth, shape, and construction shall be according to the particulars, and the cross sections for construction made out by Mr. Telford; that is to say, on level ground the bed shall be formed by removing the vegetable and other soft matters, and brought to a perfect level and consolidated state. If the ground is soft bog or morass, and less than four feet in depth, with hard ground below, the soft matter shall be removed; but if a greater depth, the whole surface shall be covered with two rows of swarded turf, the one laid with its swarded face down, and the other upwards. Where the road is formed on sloping, it shall either be cut for the whole breadth into the solid bank, with as much more as to afford a solid foundation for a fence wall, or as much shall be cut from the upper side as shall bring the lower to a proper level. If this consists

of loose soil, it must be compressed by means of water, or shall be left through a part of the winter to receive the snows and rains; but no soft, boggy, or peat substance is on any account to be laid behind the retaining walls. Where the cutting on the upper side consists of rock rubbish, gravel, or mountain clay, it will only require to be properly levelled as the work is carried on."

The following specification has been successfully acted upon in forming a road over a peat bog in Ireland: —

"When the line of the road has been traced out to the exact width and line of direction, main drains are to be cut on each side eight feet wide at top, four feet deep, and eighteen inches wide at bottom; the peat dug out of these drains is to be spread over the surface of the roadway in form of a ridge, taking care to previously cover all the very soft and swampy places with dried peat, sods, or brushwood: numerous drains are to be cut across the roadway from the one main drain to the other; they are to be three feet deep at the centre of the roadway, and four feet deep at the main drains: after the whole have remained in this state for two summer months, the bed for the roadway is to be neatly formed, with the sides on the same level, and with a convexity of half an inch in the yard.

"The carriage-way is then to be covered with six inches of clay, laid on evenly, and firmly compressed by stampers or rollers; it is to have a fall of one inch in the yard from the centre towards the sides: over the clay is to be put four inches of small gravel; it is to be frequently rolled, and, when solid and compressed, the foundation will be formed for the reception of the road materials."

CHAP. IV.

DRAINAGE.

So much depends upon the proper draining of a road, that too great attention cannot be given to this part of the business of road-making.

This operation should be carried on at the same time with the forming of the road. When a road is to be made over flat and wet land, open main drains should be cut on the field side of the road fences: these drains should communicate with the natural watercourses of the country; their size should depend upon the nature of the country and the local circumstances of the road.

In general, these side drains should be cut at least three feet deep below the level of the bed of the road; they should be one foot wide at bottom, and five feet wide at top.

If main open drains cannot be formed, in consequence of the road running along the side of a hill, or of its passing through a cutting of a hill, or of buildings or other obstructions lying close

to the road, it then becomes necessary to make covered drains on each side of the road. These should be formed of stone or brick, and be strongly and substantially built. If built with stone, they should be constructed as shown in Plate II. fig. 10. A flat stone should be laid at the bottom of the drain, the side walls should be not less than twelve inches thick, and built in regular level courses; they should be eighteen inches high, and twelve inches apart.

Particular care must be taken that the covering stones have a bearing of at least four inches on the side walls. They should have a layer of brushwood put over them; and the drain should then be filled up with gravel, or small stones. In gravel countries, or where stone is difficult to be procured, it will be necessary to build the main-side drains of brick; the side walls should be four inches thick, and three bricks high, and five inches apart, and covered with brick on the flat: these covering bricks should not be laid close together; an interval of at least half an inch should be left between each, to allow the water to enter the drain from above. Plate II. fig. 11.

In very wet clay soils, a flat tile should be

laid at the bottom of the drain, sufficiently large to extend two inches under each side wall; a layer of brushwood, or straw, should be put over the bricks, and then the drain should be filled up with cleansed gravel or small stones.

In some cases it will be necessary to build circular brick drains twelve or eighteen inches in diameter, according to circumstances; but they are expensive, and require inlets, built with brick, with iron grates. In consequence of its being necessary to build these drains with mortar, they are not so good as the open-jointed drain last described, unless there is a considerable run of water. Plate II. fig. 12.

If springs rise in the site of the road, or in the slopes of deep cuttings, stone or tile drains should be made into them, so as completely to carry away all the water.

In cuttings it is necessary to make drains of small dimensions from the centre of the road to the side drains. These drains should form an angle in the centre of the road, in the shape of a V, technically called mitre drains: the angle or splay of these drains should depend upon the inclination of the road; it should not make the inclination of the drains exceed one inch in 100; for if it be greater, the run of

the water will undermine the sides, and injure them. These mitre drains should be nine inches wide at bottom, twelve inches wide at top, and ten inches deep. These drains should be placed at about sixty yards from each other, or about thirty in the mile; but if the soil be wet, this number should be considerably increased. They are to be filled with rubble stone or cleansed gravel. If gravel is used, a draining tile should be laid along the bottom before the gravel is put on.

The upper part of these mitre drains should communicate with the road materials, so as to draw the water from them.

According to the inclinations of a road, and the form and wetness of the country through which it passes, cross drains of good masonry should be built under the road, having their extremities carried under the road fences.

One of these drains should be made wherever the water would lie on one side of the road, and can only be got rid of by carrying it to the other side. When the road passes along the slope of a hill or mountain, a great number of these drains are necessary to carry off the water that collects in the channel of the road on the side next the high ground. They should be placed

at from 50 to 100 yards' distance from each other, according to the declivity of the hill; so that the side channels may not be cut by carrying water too far. In these situations inlets should be built of masonry, to carry the water from the side channel of the road into the cross drains. The manner of building an inlet will be described in the chapter on Road Masonry. Numerous outlets should also be made from the side channels of the road, under the footpaths, or wastes and fences, into the field ditches.

In mountainous countries, where the road passes along the slopes of the hills, it is necessary to carry open or catchwater drains, branching from the upper ends of the cross drains, in an inclined direction, so as to catch the surface water before it can reach the road.

After all these precautions have been taken, the preservation of the surface of the road from injury by water should be further secured, by giving to the surface of it a proper convexity in its cross section, and by making regular side channels.

These side channels will be formed by the angle where the slope of the side parts of the surface of the road abuts against the edge of the footpath, or other defining bounds of the

roadway. They will be capable of carrying off a great quantity of water, without being made into the form of a square-sided drain.

Attention to make the surface of a road of a proper convex form is particularly necessary on hills, in order that the water may have a tendency to fall from the centre to the sides, in place of running from the sides to the middle part of the road, which it certainly will do unless the side channels are kept below the centre of the road, in the manner hereafter described.

On all hills the greatest care should, also, be taken to keep the side channels always open; for, if they are obstructed with dirt, the water will find its way over the middle of the road, and cut channels in it. The side channels of a road should be all thoroughly repaired as well as all the road drains before the approach of winter, and again after the winter is over; but, besides these repairs at fixed periods, daily attention should be given to take care that no obstruction gets into them.

Whenever a branch or field road joins a main road, it should not be allowed to interfere with the side channel: in order to secure this object, the point of junction should always be on the field side of the side channel; unless this is the

case, the branch or field road will, when on a higher level than the main road, carry its surface water upon the main road.

In addition to all these means recommended to be adopted for securing the drainage of a road, it is of the utmost importance that evaporation should have full effect in drying up the surface of a road, by allowing the sun and wind to act upon it in the freest manner.

The necessity of giving a road a good exposure has already been mentioned under the head of "Laying out a Road;" and the value of a rapid evaporation will be more fully explained when the repairing of roads is brought under consideration.

If roads be kept dry, they will be maintained in a good state, with proportionally less expense. It has been well observed, that the statuary cannot saw his marble, nor the lapidary cut his jewels, without the assistance of the powder of the specific materials on which he is acting: this, when combined with water, produces sufficient attrition to accomplish his purpose.

A similar effect is produced on roads, since the reduced particles of the materials, when wet, assist the wheels in rapidly grinding down the surface.

A more particular description of the mode of constructing the several drains which have been mentioned, will be given in the chapter on Road Masonry.

CHAP. V.

DIFFERENT KINDS OF ROADS, AND MODES OF CONSTRUCTING THEM.

The different kinds of roads may be distinguished and described as follows:—

1st. Iron railways.

2d. Paved roads.

3d. Roads of which the surface is partly paved and partly made with broken stones, or other materials.

4th. Roads with a foundation of pavement and a surface of broken stones.

5th. Roads with a foundation of rubble stones, and a surface of broken stones or gravel.

6th. Roads made with broken stones laid on the natural soil.

7th. Roads made with gravel laid on the natural soil.

IRON RAILWAYS.

When iron railways were first introduced into England cannot be clearly ascertained: they were probably first used in iron manufac-

tories for local and private purposes, and as an improvement on the wooden rails previously employed at coal mines and stone quarries.

Mr. Wood, in his treatise on railroads, supposes that timber railways were first introduced about the year 1602, or between that and 1649, by Beaumont, a speculator in coal mines, in the neighbourhood of Newcastle-upon-Tyne.

It is certain that timber railways were in very general use in the collieries of North Cumberland and Durham about the commencement of the eighteenth century. It is stated, that on railways of this description a horse could draw about forty-two hundred weight; the usual load for one horse upon the common roads being, at that time, about seven hundred weight.

The first improvement which took place in railways of this description, was that of laying down double rails, or one rail over the other, the upper being pinned down to the under one; by which means it could be replaced by a new one when it was worn out, without raising or disturbing the sleepers or the under rails. The next improvement was securing the upper rail from injury by covering it with a plate of iron, and substituting iron wheels for wooden ones, about the year 1753.

At what period the next improvement took place, namely, that of using iron rails instead of wooden ones, is not exactly known. Mr. Robert Stephenson, of Edinburgh, says, that the first cast-iron rails were made at Colebrookdale, in Shropshire, in the year 1767.

Mr. Wood states that Curr, in his "Coal Viewer and Engine Builder," published in 1797, says, "that the making and use of iron railroads were the first of my inventions, and were introduced at the Sheffield colliery about twenty-one years ago." They were not, however, generally known, until they were introduced by Mr. Outram, engineer of the Butterly Works, in Derbyshire, many years after.

In 1789, Mr. Jessop introduced the edge-rail on the public railroad at Loughborough; this was a considerable improvement of the old system of flat plates with flanches. The only great improvement which has since taken place, is the making of the edge-rails of wrought instead of cast iron, and the fixing of them in a more firm manner to the blocks, or sleepers.

Mr. Wood states, that iron rails were tried at Wallbattle Colliery about the year 1805,

by Mr. C. Nixon; but Mr. Stephenson says, they were first introduced about the year 1815, at Lord Carlisle's coal works on Tindall Fell, Cumberland. According, however, to the statement of Mr. Thomson, the present agent, they were laid down on that railroad in 1808. Since that period they were not extensively used until after the year 1824.

Previous to 1794 there was no public railway. In that year, Mr. Samuel Homfray obtained an act of parliament for constructing an iron railway between Cardiff and Merthyr-Tydvil, in South Wales, for the use of the public, on paying certain tonnage rates per mile. Soon after 1797, iron railways began to be constructed in Shropshire, as branches to the canals, and in other parts of England.

It is generally allowed, that on a railway well constructed, and laid with a declivity of one in ninety-six, or fifty-five feet in a mile, one horse will readily take down waggons containing from twelve to fifteen tons, and bring back the same waggons with four tons in them, and that on a level railway a horse can draw twelve tons.

An ingenious contrivance has been adopted on the Darlington railway, for increasing the work performed by the horses. Great part of

the traffic is in one direction, and the railway happens to be so constructed that, on a considerable portion of its length, the carriages descend by their own gravity when loaded.

A low truck, or platform, accompanies the train of loaded waggons; on this truck the horses are carried along those parts of the road where the carriages are moved by gravity: by these means they are enabled to do much more work than they otherwise could do; for, by the time the carriages arrive at the bottom of the descent, the horses are in some measure rested, and are enabled to drag on the train of waggons, with fresh vigour, to the next inclined plane, where they again ascend the truck.

Mr. Storey states that "previous to carriages being used for the horses to ride on, a week's work, of six days, was eighty-seven miles with twelve tons of coals, and five tons and a half of empty carriages, and eighty-seven miles back with five tons and a half of empty carriages; in all, 174 miles. A week's work, after using the horse carriage, was 120 miles with twelve tons of coals, and five tons and a half of empty carriages, and 120 miles with five tons and a half of empty carriages; in all, 240 miles, or one third

more work, and the horses improved in condition; whereas formerly the horses grew worse in condition."*

It is stated in the "Treatise on the Horse," published by the Society for the Diffusion of Useful Knowledge, as an unparalleled instance of the power of the horse, that one horse drew on the Surrey railroad, near Croydon, twelve waggons loaded with stones, each waggon weighing about three tons, a distance of six miles, with apparent ease, in one hour and forty-one minutes.

On the Penrhyn railway, in Caernarvonshire, two horses draw twenty-four waggons one stage six times per day, which carry twenty-four tons each journey, or one hundred and forty-four tons per day. This railway is six miles and a quarter in length, and is divided into five stages; it falls at the rate of one in ninety-six, and has three inclined planes.

In speaking of the horses employed upon the Backworth and Killingworth railways, Mr. Wood says, "the horses are extremely powerful. The average resistance with the loaded carriages is 42 pounds, and with the empty carriages, 189 pounds, giving a mean of 115 pounds: they

* Mr. Storey's Report; Wood on Railways, page 303.

traverse the distance backwards and forwards most frequently eight times a day, making nineteen miles. This may be taken as the maximum performance of horses, and will show the resistance which a very powerful horse is capable of overcoming occasionally."

The expense of constructing railways depends upon the nature of the ground they are made over, and the purpose for which they are intended. In many situations, where the trade is altogether a descending one, and water scarce, they are preferable to canals, and may be constructed cheaper; but for general traffic over a wide extent of country, they do not afford as cheap a means of conveyance as canals.

In some instances, railways have been constructed for 1000*l.* per mile, but in others, the Manchester and Liverpool, for instance, the expense per mile has exceeded 30,000*l.*

It is stated in the Quarterly Review, No. LXII. p. 363., that the general average of a number of railroads, some tram-rails, others edge-rails, some of cast iron, others of wrought iron, of upwards of 500 miles extent, is as nearly as possible 4000*l.* per mile, allowing them a double set of tracks; and the writer very justly remarks,

"From the imperfections of these old railroads we may extend the average to 5000*l.* per mile." Mr. Tredgold estimates the annual repair of a railroad at 557*l.* per mile.

Mr. Stephenson estimated the cost of making a railroad from London to Birmingham, at 2,500,000*l.*, or 21,756*l.* per mile; but other engineers have calculated the total expense at about 3,500,000*l.*, or at 30,400*l.* per mile.

The annual expense of keeping a railroad in repair depends much upon the velocity with which the waggons are drawn over it. Mr. Walker, in his Report to the Directors of the Manchester and Liverpool Railroad, states, "that, as the speed with engines is greater than with horses, the injury is greater in case of any irregularity."

It has been well ascertained, that railroads on which horses are employed are always found in much better order and repair than those on which locomotive engines are used.

The relative expense of transporting goods upon canals, railways, and common roads, may be estimated as follows: — From various observations which have been made on the work actually performed by horses on several railways, it may be assumed, that the greatest effect

produced by horses is twelve tons gross, drawn over a space of twenty miles per day; and, as the waggons employed on railways are generally one-third of the gross weight, the net weight of the goods carried will be eight tons over twenty miles per day, by one horse, or 160 tons over one mile, at the average velocity of two miles per hour. The expense may be taken at twopence per ton per mile.

On canals, one horse will draw a boat containing twenty-five tons of goods, over a space of sixteen miles per day, at the speed of two miles and a half per hour: this is equivalent to $25 \times 16 = 400$ tons of merchandise carried over one mile per day, or two and a half times as much as on a railway. The actual expense of transporting goods by canal, is only one halfpenny per ton per mile, including boat-hire, steersman, wages, and horse power.*

In Scotland and Ireland, where the roads are made with broken stones, and where the practice is to use one-horse carts, the work which horses perform may be taken at 25 cwt. exclusive of the cart. But in England, where waggons are used,

* This has been the regular charge on the Ellesmere Canal for some years, and is now introduced on the Oxford canals, and several others.

and the roads are not so hard, the work of horses may be taken at 15 cwt. In the latter case, the average cost is about ninepence per ton per mile, including the wear and tear of the carts, and the wages of the drivers. In some parts of the country the cost is sixpence per mile, but in other parts, as near London, it is one shilling.

The expense of carrying goods by locomotive engines on railways much exceeds that on canals or on railways with horses.

Since the opening of the Liverpool and Manchester railway, locomotive engines have been very much improved. On that line of railway, goods are carried at from eight to ten miles per hour for 4½*d.* per ton per mile, and passengers are carried at the same speed from Manchester to Liverpool, or *vice versâ*, for 3*s.* 6*d.*, and in the first class of carriages, with a velocity of from fifteen to twenty miles per hour, for 7*s.*

The locomotive engines cost, in the first instance, from 600*l.* to 1000*l.*; the waggons for goods, about 40*l.*; and the carriages for passengers, about 200*l.* each. The locomotive engines are able to draw immense loads, but they are extremely expensive. The annual expense

of each engine is estimated at 1500*l*., including wear and tear, and fuel and attendance.

In speaking of the comparative performances of locomotive engines and horses on railways, Mr. Wood says:—

"The least performance of a locomotive engine will be equal to that of eighteen horses, supposing that an average velocity of twelve miles per hour for eight hours in the day be attained. Much of this will depend upon the length of the railway, and the nature of the traffic in which they are employed: in short lines of road, where the delays in changing, &c., produce considerable stops, this performance will be diminished; but still their performance will equal that of a considerable number of horses. The relative cost will, of course, depend much upon the situation of the district in which they are used, with respect to the price of fuel, and other circumstances; and their performance, upon the length and features of the railroad on which they are made to travel. In a general way, perhaps, at the rate of speed above assigned, we may state the cost of one locomotive engine equal to that of four horses and their attendants. So long, therefore, as the performance of a locomotive engine exceeds that of four horses, the economy of transit will be in favour of engines; and where

the length of the railway, and the nature of the traffic, will allow of a maximum performance, then their relative utility, compared with horses, will be as four and a half to one."*

From actual experience, however, it will be found that the expense of locomotive engines, travelling at a velocity of ten to fifteen miles per hour on the Manchester and Liverpool railway, far exceeds what was contemplated; but the period is so short since they first commenced running, that it is impossible, as yet, to say what the ultimate expense may be; for, at present, all the works and machinery are new, and will, of course, have cost less for repairs during the first few years than they will hereafter.

The annual expense of working a locomotive engine on the Liverpool and Manchester railway is stated, by Mr. Grahame of Glasgow, to be 2107*l.* 14*s.*, instead of 270*l.* 12*s.* 10*d.*, as first supposed it would have been. He says, "Previous to opening the Liverpool railway, Messrs. Stephenson and Lock, engineers to the railway, judging from various trials and experiments made on the railway, calculated the expense of an engine

* Wood on Railways, p. 434.

doing nine hundred and thirty-seven trips yearly, or three trips per day at the rate of fifteen miles per hour, dragging a dead weight of thirty tons, at 324*l.* 12*s.* 10*d.*, including a sum of 54*l.* laid aside each year for the replacement of the engine, and interest on cost; or the cost of the motive power of each trip was calculated by them at a sum something under six shillings and sixpence.

"It does not appear by the Liverpool and Manchester railway reports what number of engines they had in employment during the year 1831: but this is of little importance, as the number of thirty-mile trips performed by the engines is specially stated, with the costs of these trips; and this cost includes *merely the price of coke consumed, the cost of repairs, and the engine men's wages, without any allowance whatever for interest of capital, or replacement of the engines themselves.*

"Now, the exact number of thirty-mile trips made by the Liverpool railway engines in the six months of the year 1831 was 5392, of which 2944 were with carriages and passengers; the gross weight dragged not exceeding fourteen tons. The expense or cost of these 5392 trips, for coke, wages, and repairs alone (allowing nothing for replacement), was 12,203*l.* 5*s.* 6*d.*,

or a little above 2*l*. 5*s*. 3*d*. per trip; or the bare cost of one engine doing nine hundred and thirty-six trips was 2107*l*. 14*s*., instead of 207*l*. 12*s*. 10*d*."

The plan of constructing a railway should be arranged so as to be adapted to the purposes for which it is intended. If for local or private purposes, the same expense is not necessary as when the railway is for general and public traffic.

In the former case, the rails should not be so heavy, so strong, or so expensive as when employed for the latter, and the blocks may be of much less weight, and the fastenings less perfect.

To form a perfect railway for general traffic, on which locomotive engines are to be employed, the surface of the ground over which it is to be made should be reduced by cutting, filling, or tunnelling, to rates of inclination not exceeding one in 300. The rails should be of wrought iron of not less than fifty pounds to the yard, and they should be laid on blocks of hard solid stone, each of not less than five cubic feet.

These blocks should be set on a firm, solid foundation of hard broken stones, at least two feet thick, technically called ballasting. The space between the blocks should be filled up with rubble stones, and the whole should be covered

with gravel up to the level of the bottom of the rails.

What has been said in the fourth chapter, relating to the draining of a turnpike road, should be strictly attended to in constructing railways.

Railroads, on which locomotive engines are employed, should not be carried across a turnpike road on the same level with the road, but by tunnels or viaducts. When horses are employed, it is not so objectionable to cross roads on the same level; it should, however, if possible be avoided: when it is impossible, great care should be taken to keep the top of the rails on a level with the surface of the road, or rather below it, and the space between the rails should be kept always filled to the same level.

Notwithstanding it seems to be universally believed, that the practicability of making use of locomotive steam engines on railroads has been established by what has taken place on the Manchester and Liverpool railway, there are many competent judges who are of opinion that it would not have succeeded, had it not been for the peculiar circumstance of its forming a direct communication between two such very populous, opulent, and enterprising trading towns as Manchester and Liverpool.

In the twentieth number of the Foreign Quarterly Review there is an article on locomotive engines and railroads, in which it is asserted, that "every attempt yet made to render steam carriages on railroads the means of economical and regular inland communication has totally and absolutely failed."

The following is an epitome of the argument by which this proposition is supported. It is laid down as a principle that steam will be superior to water, or wind, or horse-power only when it can be more easily, uniformly, and economically applied; and then it is maintained, that as yet it has not been more economically applied than horse-power, in consequence of the immense expense which has attended every plan which has been tried. For it appears, on examining the half year's account to July, 1832, of the Liverpool and Manchester railway company, printed for the use of the subscribers, that the repairs of the railway cost 7331*l.* in the preceding six months, and that the repairs of the engines in the same period cost 10,582*l.*, making the amount of expense for repairs in a year 35,826*l.*, on a line of railway of thirty miles, being at the rate of 1194*l.* a mile.

The article proceeds to state, that the cause of this vast expense is the huge, disproportioned,

and clumsy masses of mechanism of which the steam engines consist: these would produce, by their weight and jolts, their own rapid destruction, as well as that of the railway, if it were not for the repairs which are constantly going on. This injury to the engines is occasioned in consequence of having no contrivance to prevent the jolts from being communicated to them which the wheels are exposed to in passing over the railway; and these jolts are occasioned by the unavoidable defects common to all railroads; for a railroad is not, by any means, what many suppose it to be, a perfectly smooth and even road of metal; but being composed of separate rails of iron, laid one following another, in lengths of not more than six yards, there are frequent breaks in the line, although almost imperceptible, in consequence of its being impossible to make perfect joinings of the rails, owing to the necessity of openings being kept between them to admit of their expansion and contraction with the variation of the temperature. In addition to this, the rails are not supported uniformly, by lying on the surface of the road, but rest on stones or sleepers, placed at the distance of a yard from each other. According, therefore, as heavy weights pass over the rails with great velocity, these sleepers are driven deeper into the ground,

some more deeply than others, so that the surface of the line of rails becomes uneven.

Though this defect is not easily detected by the eye, it appears on close examination with instruments, and on watching the motion of a carriage; for the wheels, on passing every joining of the rails, receive a jolt which causes a change of direction, first towards one side and then towards the other: hence the carriage rolls very much, whilst at every swing one wheel or the other strikes a rail with considerable violence.

In order to remedy the great defect of having no contrivance to prevent the jolts from being communicated to the engines which the wheels are exposed to, an arrangement is indispensably necessary for supporting the carriage body and the whole moving machinery upon flexible springs, so that the whole may vibrate freely in every direction, and yet admit of its being impelled forwards with uniform power and velocity. But to apply a continuous force to wheels through a set of springs from a machine that is permitted to swing backwards and forwards, so as to be now nearer to them and then further off, implies a combination of stiffness and flexibility which seems an absolute contradiction. Such an arrangement requires that those parts should

be rendered movable, which it is of the greatest importance to preserve immovable.

The article here quoted concludes by observing, —"But the failure which has hitherto attended all attempts at the steam carriage, it is right to say, has arisen, not from any necessary incompatibility between the nature of steam, and the particular application of its power to railroads, but from the deficiency of the inventions, in some of the great elements of structure that are essential to its success.

"We may, therefore, still look forward to the substitution of its use for horse-power in bringing about a great and beneficial change in the moral, political, and commercial state of the empire." *

PAVED ROADS.

In situations where canals cannot be constructed, either from want of water, or other circumstances, and where the description and quantity of traffic, or local obstructions, do not justify the expense of forming a railroad, paved roads made on proper principles would be found much better for conveying goods than turnpike roads, constructed as they usually are.

* See No. 20. of the Foreign Quarterly Review, Article VII.

The advantages which may be derived from paved roads, as a means of transport, have been too much over-looked; and therefore it is very important to show how much superior a well made paved road is to a common road in enabling horses to draw very large burdens.

On a smooth, well made pavement, quite horizontal, it appears, from the experiments made with Mr. Macneill's machine, that the resistance to draught is not more than the 100th part of the weight of the carriage and its load, when the carriage is properly constructed, and mounted on straight and cylindrical axles.* According to this a horse of great power would be able to draw on such a road, if horizontal, six tons and three quarters; and if with no greater inclination than 1 in 50, two tons and a quarter.

The following statement on pavements is taken from the evidence of Mr. Walker, given before a select committee of the House of Commons, upon the Commercial Road from London to the West India Docks:—

"It is not, I am sure, overstating the advantages of paving, but rather otherwise, to say,

* See Seventh Report on the Holyhead Road.

taking the year through, two horses will do as much or more work with the same labour to themselves upon a paved road than three upon a gravelled road, if the traffic on the gravelled road is considerable; and if the effect of this is brought into figures, the saving of the expense of carriage will be found to be very great when compared with the cost of paving. If the annual tonnage upon the Commercial Road be taken at 250,000 tons, and at the rate of only three shillings per ton from the Docks, it could not, on a gravel road, be done under four shillings and six-pence, say, however, four shillings, or one third per ton difference, which makes a saving of 12,500*l.* in one year.

"I think I am under the mark in all these figures; and I am convinced, therefore, that the introduction of paving would, in many cases, be productive of great advantages."

Mr. Walker further says, that "during thirteen years that the East India Docks' branch has been paved, the paving has not cost twenty pounds in repairs, although the waggons, each weighing about five tons, with the whole of the East India produce, which is brought from the Docks by land, have passed all that time in one track upon it; and a great deal of heavy country traffic for the last eight years, when a

communication was formed with the county of Essex."*

This road has been referred to, not by way of showing a perfect specimen of pavement, but generally to point out the advantages of paved roads; for this road, in consequence of the plan of Mr. Walker not having been strictly attended to, was by no means originally constructed in so perfect a manner as it might have been.

Still, however, it was by far the best specimen of pavement that had been executed; and it has fully established, by experience, the great advantages which the public may obtain by making a paved road for transporting merchandise, when it is not possible to make a canal or railway.

The plan of paving this road was altered in 1829: large blocks of granite, five or six feet in length, sixteen inches wide, and twelve inches deep, were laid for the wheels to run upon, as on a tramroad of iron, except that there is no flanche. The space between the granite blocks is paved. The plan has succeeded, as may be seen from the following Report of Mr. Walker to the trustees of this road:—

"I beg to report the results of the expe-

* See Report of the Committee of the House of Commons, on Turnpike Roads, in 1819.

riments made this day upon the stone tramway now forming on the Commercial Road, before you, accompanied by the Chairman of the West India Dock Company, and Mr. Colville, one of the directors.

"The experiments were made upon the space between the West India Dock-gate and the first turnpike upon the Commercial Road, with a very good town-made waggon, belonging to Messrs. Smith and Sons, distillers, and a stone truck, belonging to Messrs. Freeman.

"The dust had been swept off the tramway in the morning. The distance is 550 feet, of which 250 feet nearest the Dock-gate rises 1 foot, or one in 250, and the other 300 feet rises about 2½ feet, or 1 in 116.

"The whole rise in the 550 feet is 3½ feet, or 1 in 155.

"The gravity of one ton upon the lower length is, therefore, 2240 lbs. divided by 250, or nearly 9 lbs. Upon the upper length it is 2240 lbs. divided by 116, or 19½ lbs., and the average of gravity upon the whole length is 2240 divided by 155, or 14½ lbs.

"Experiment 1st. The general average resistance of four tons gross (viz. waggon 1 ton 16 cwt. and goods 2 tons 4 cwt.), as ascertained by your chairman (C. H. Turner, Esq.) and Mr. Colvile,

by means of a spring weighing machine, was 127 lbs.; from which, if we deduct the gravity of 4 tons, or 19½ lbs. multiplied by 4, say 77 lbs., there is left, for the friction of 4 tons, 50 lbs., which gives for the friction of 1 ton 12½ lbs., 1/180th of the whole weight moved.

"This friction is not more than upon the best constructed edge railway. I consider that the greater size of our wheels, and there being no flanche, compensate for the roughness of the stones (from their being newly laid), as compared with an iron railway.

"Experiment 2d. A pony 12½ hands high, weight 4½ cwt., drew upon the upper part in your presence, and afterwards upon the lower part in your and the directors' presence, six tons (gross). I was not aware that the difference of inclination of the two parts was so great, or he should have gone over the upper length again, — he had done it more than once before.

"Taking, therefore, the upper part on the rise of 1 in 116, the pony's exertion was,

		lbs.
Gravity 19⅓ lbs. multiplied by 6, or	-	116
Friction 12½ lbs. multiplied by 6, or	-	75
	Making together	191

and 191 lbs. divided by 12½ lbs. (the friction of one ton) gives 15 tons.

"The pony's work, therefore, was equal to *fifteen tons* drawn upon a level road.

"Experiment 3d. The waggon, loaded as in the preceding experiment, being turned round and started by the pony's exertion, ran down the whole length to the Dock-gate with increasing velocity (the pony not drawing it), and for a distance off the tramway, before it could be stopped; consequently the average fall of 1 in 155 exceeded the resistance by friction.

"Experiment 4th. A powerful horse (weight 14 cwt.) drew 12 tons gross (the waggon and truck loaded) from the West India Dock-gate to the turnpike, at the rate of 4 miles per hour.

"Taking, then, the upper length, or a rise of 1 in 116, we have

		lbs.
Gravity 12 times $19\frac{1}{3}$ lbs., or	-	232
Friction 12 times $12\frac{1}{2}$ lbs., or	-	150
Making together		382

and 382 lbs. divided by $12\frac{1}{2}$ lbs. gives $30\frac{1}{2}$ tons.

"The horse's work was therefore the same as if he had been drawing $30\frac{1}{2}$ tons upon the level.

"The full average work of a horse, per day, is 150 lbs. moved 20 miles; consequently the pony was exerting one fourth more than the

average work of one horse through the day; and the horse was doing the work of 2½ horses.

"The horse appeared to go easily; but the exertion was, of course, too great to be continued for any considerable time, so as to form a basis for general calculation.

"Upon the whole, I think the conclusion is, that if the road were level, the work of a London draught horse upon the tramway would be ten tons (gross); but as the Commercial Road rises towards London, a deduction must be made from this for gravity, the amount of which depends upon the inclination of the road, and is common to all kinds of roads and railways. Therefore, taking all things into consideration, I am of opinion that six tons (gross) from the Docks to Whitechapel, and a greater weight from Whitechapel to the Docks, may be considered a proper load for one horse on the tramway."

A common opinion prevails, that because paved streets have almost every where been suffered to be rough and imperfect, all pavements must necessarily be rough and bad; but a slight degree of consideration will show that this opinion is without foundation, and that, in point of fact, the cause of rough and bad pavements is bad management, arising from the ignorance of those employed to make them,

or the want of sufficient funds for executing good work.

The chief defects of all pavements arise from neglecting to give the stones a proper shape, and to construct a substantial foundation to support them.

The foundation for the London pavements has commonly been formed with all sorts of old rotten materials, without having uniformity in texture or solidity.

This makes the bottoming of unequal strength, and the consequence is, that after the pavement has been laid upon it, the weaker parts give way, while the stronger remain firm, so that the surface of the street becomes low in some places, and high in others, and very soon rough and out of order.

But the effect of this bottoming is visible in another way; for in consequence of the defective shape of the stones, and also of the defective manner in which they are set, there is a quantity of soft earth between them, which serves to conduct the water which falls on the pavement through the joints of the stones into the body of earth that lies under them. But when the water gets into this earth, it forms a bed of mud, and the heavy weights passing over the paving stones press them into it, and then

the mud, not being able to resist the pressure, rises upwards between the joints to the surface of the pavement.

In making some of the new pavements in London, more attention has been paid to the foundation than formerly, but still not so much as there should have been. Fleet Street, for instance, was paved with considerable care; the stones were properly shaped and dressed, and evenly laid: the ground was dug out twelve or eighteen inches deep, and a body of broken stones was put into the space thus cleared out for a foundation, and the joints of the paving stones, when set, were grouted with liquid lime. Yet, notwithstanding all this, the pavement soon got out of order, and became uneven and extremely defective in a few months after it was made. The cause of this failure was the stones for the foundation having been thrown in loosely, by cart-loads at a time, and merely levelled before the paving stones were laid on.

The great defects in the London pavement, with respect to the shape of the paving stones, and to proper bottoming, are, in a great measure, to be attributed to the errors committed by the persons, who have had the management of making contracts for it.

They have acted too much on the principle of getting cheap work, and to accomplish this have neglected the main point of securing good work. In this way they have promoted a system of inconsiderate competition, and thereby reduced the price of paving work so unreasonably low, as to make it impossible for contractors to provide the best materials, and to bestow the necessary portion of labour on dressing and setting them, without loss.

Besides this, the managers of the pavements have sometimes committed another error, in requiring the contractors to execute their work by the superficial square yard, of a certain depth, without adding conditions respecting the weight of the stones to be put into a square yard, and without requiring the close joining of the stones. As contractors purchase the stones by weight, the less square (that is, the more imperfect) they are, the more profit they will have on each superficial yard; so also in proportion as the joints between the stones are wide, fewer stones will be used, and the work will be proportionably profitable to them, and defective for the use of the public.

Having thus shortly explained the principal defects of the London practice of paving, the mode that seems fit to be adopted in its stead shall now be described.

The first object to be secured is, a good foundation; for this purpose, a bed should be formed with a convexity of two inches to ten feet, so as to admit of twelve inches of broken stones being laid upon it. These should be put on in layers of four inches at a time. After the first layer is put on, the street should be kept open for carriages to pass over it. When this first layer has become firm and consolidated, then another layer of four inches should be put on, and worked in as before, care being taken to rake the ruts and tracks of the wheels of carriages, so that the surface may become smooth, and consolidated. The same process should be repeated with the third layer of stones, by which means, a solid and firm foundation will be established, of twelve inches in thickness, for the dressed paving stones to lie upon.*

After this operation is accomplished, the next

* Mr. Edgeworth says, in his Essay on Roads, "In all pavements, the first thing to be attended to is the foundation This must be made of strong and uniform materials, well rammed together, and accurately formed to correspond with the figure of the superincumbent pavement. This has nowhere been more effectually accomplished than in some late pavement in Dublin. Major Taylor, who is at the head of the paving board, before he began to pave a street, first made a good gravel road, and left it to be beaten down by carriages for several months: it then became a fit foundation for a good pavement." Page 33.

thing to be attended to, is to provide proper paving-stones. These should be cut into a rectangular shape, and of the hardest quality that can be procured; granite is the best, but whinstones, some descriptions of limestone, and freestone, will answer the purpose.

With regard to the size of the stones, that should be regulated by the intercourse.* The streets should be divided into three classes, according as the thoroughfare is greater or less. For streets of the first class, or greatest thoroughfare, the stones should be ten inches in depth, from ten to fifteen inches in length, and from six to eight inches in breadth on the face. For streets of the second class the stones should be eight inches in depth, from eight to twelve inches in length, and from five to seven inches in breadth on the face. For streets of the third class, the stones should be six inches in depth, from six to ten inches in length, and from four to six inches in breadth on the face.

After having prepared a proper bottoming,

* The following is taken from Encyclopédie de l'Ingénieur, vol. i. p. 355.:—"In France, pavements are made with stones cut with the hammer, of seven or eight inches on every side, like so many dice: these stones are laid in lines, on a bed of sand, from seven to eight inches in thickness. River sand is the best."

the greatest care must then be bestowed in setting the stones. Fine gravel must be provided, cleansed from all earth, to form a bed over the bottoming of two inches thick for the stones to be set in. Strong mortar must also be provided; and, besides the common tools, each pavior should have a wooden maul, the head of which should be made of beech or elm, and should weigh about fourteen pounds. The stones should be selected so that they may be laid in even courses, and so as to match, as nearly as possible, in each course with regard to breadth and depth.

The pavior should first set a stone on the gravel bed, by striking it strongly downwards with the maul, and then on its sides. Then he should lift it out of its berth, and put mortar on the sides of the two adjoining stones; after which he should again place the stone in its berth, and strike it as hard as he can, downwards and sideways, with the maul, till it is fastened in the position in which it is to remain. Each stone should be set in this manner; and, when the pavement is finished, it will be so firm as not to require ramming.*

* See Mr. Telford's Report on Pavements, in the Appendix, No. 2.; and Mr. James Walker's observations on the same subject, Appendix, No. 3.

The crossings for foot-passengers should be raised above the level of the pavement, by giving a moderate convexity to the bottoming. They should be made with stones of the size for streets of the first class, more accurately dressed.

The pavement should be formed with a regular, but very moderate convex surface, by giving the bed for it the convexity already meutioned: there should be no gutter or other channel but that which will be formed by the angle made by the surface of the pavement abutting on the curb-stone. The curb-stone of the pavement should be made of long blocks of stone, of a quality sufficiently hard to resist the shocks of wheels striking it. These blocks should be bedded in gravel, and joined with cement: they should be sunk four inches at least into the ground, and be six inches above the pavement.

The foot pavements should be made of well-dressed flags; each flag to have its sides rectangular, and to be set in mortar with a very close joint upon a strong gravel bed of six inches in depth. The flagstones should be at least two inches and a half thick; the surface of the foot pavements should have a declivity at the rate of one inch in ten feet, towards the street.

In those towns where the intercourse of foot passengers is considerable, the greatest possible breadth should be given to the foot pavements. In general, this important accommodation is too much neglected.

In making a contract for paving a street, it should be so arranged that the work shall be paid for by the superficial yard. A specification should be connected with the contract, requiring that the natural soil shall be removed to a certain depth, and made level; that the bottoming shall consist of certain prescribed materials, and of a fixed depth and convexity, and be laid on in the manner already described; that the stones shall be of a certain shape, and size, and weight in each superficial yard; and that they shall be set in a regular manner.

The specification should also provide that an inspector shall be appointed to see that the conditions of the contract are fulfilled.

A drawing of the transverse section of the proposed pavement should be made, and attached to the contract. (See Plate III. Fig. 1.) But, besides these precautions, the persons who have the management of the business of making the contract should take care to ascertain the sum for which an honest and skilful

contractor can execute the work in a proper manner. This is necessary in order that they may avoid making a bargain on such terms as will oblige the contractor to have recourse to inferior materials and workmanship, to save himself from losing money by his undertaking. It is not, by any means, difficult to ascertain exactly what each part of this kind of work will cost, and to make an accurate estimate of the total expense to be incurred.

Such an estimate ought always to be made by a competent person in the employment of the commissioners or other persons who have to manage contracts for pavements. And in place of promoting an indiscriminate competition for the purpose of lowering the price, without regard to the quality of the work to be performed, the commissioners or other managers ought to call upon a few of the most respectable paving contractors for proposals; and give the contract to the bidder who comes nearest to the estimate of their own officer. If no fair tender be made, recourse may then be had to advertising for a contract.

With respect to the repairing of paved streets, this work should be done by contract. The price may be fixed by the suuerficial yard; but

the manner of doing the work should be minutely described in a specification.

Whenever any pavement is taken up, if only a few stones, there ought to be fresh broken stones provided for making good the bottoming. A principal cause of the bad state of the pavement in London is neglecting the repairing of them in due time. After a pavement is newly laid, it is usually left without any repairs until it is in a ruinous state; but, instead of this, constant attention should be paid to it, and as soon as a single stone gets out of its proper bearing it should be taken up, and relaid with new bottoming. In case of breaking up the pavement for water or gas pipes, it should be specified that a complete bottoming of stones should be first laid down over the pipes, similar in every respect to that provided for the first making of the pavement.

The paving stones should be laid on loose at first, and left till the bottoming is consolidated, and then they should be taken up and carefully set in mortar.

Paved streets have been objected to on account of the noise made by carriages passing over them. The noise chiefly arises from the boxes of the wheels striking the arms of the axle-

trees; and, therefore, when a paved street is exceedingly rough, the strokes of the axles are frequent and violent. But when a paved street is properly made, the surface of it will be comparatively smooth, and then both the number and force of the strokes of the axles on the boxes will be greatly reduced, and consequently the noise made by carriages. When a carriage passes from a rough to a well-made pavement, the difference of sound is immediately perceivable.

It is supposed by some persons that if the streets were paved in the way proposed their surface would be too smooth for horses to go safely over them; but this supposition is not well founded, except when that kind of stone is used which becomes polished by wear.

Scotch granite and some other kinds of stone do not become polished; and therefore pavements made with them will never have so smooth a surface as to be unfit for horses. A horse properly shod, will seldom slip on a pavement, or fall, unless when thrown down by being turned too short, or other careless management.

The enormous expense which has been in-

curred by adopting the plan of broken stone streets in London, in place of pavements, is fully established by the following return, which was presented to the House of Commons in the year 1827.

By this return it appears that the first cost of converting 1 mile 250 yards from a pavement into broken stone road was 12,842*l.*; and that the annual expense of maintaining this 1 mile 250 yards has been 4003*l.*, being at the rate of 1*s.* 9*d.* per superficial square yard.

"M'ADAM'S ROADS:

Regent Street, Whitehall, and Palace Yard Streets.

"Account of all sums expended by the commissioners acting under 5 Geo. IV. c. 100. and 6 Geo. IV. c. 38., in converting Regent Street, Whitehall, and Palace Yard Streets, into broken stone roads, including the value of the paving stones converted into broken stones; also, of the expense incurred in maintaining these roads in repair, including scraping and watering, and all other expenses in the year ending 5th January,

1827; and showing the number of lineal yards, and of superficial square yards, in the Regent Street District, the Whitehall District, and Palace Yard District; viz.

	£	s.	d.
"The cost of converting Regent Street, Whitehall, and Palace Yard Streets into broken stone roads has been - -	6055	8	3
"And the value of the old pavement taken up and broken for that purpose is estimated at -	6787	7	0
	£12,842	15	3

	£	s.	d.
"The cost of maintaining these Roads in repair, including scraping, and every expense, except watering, in the year ended 5th January, 1827, was - -	4003	18	4
"The cost of watering the said roads in the year ended 5th January, 1827, was - -	628	11	0
	£4632	9	4

"The extent of the said roads is as under; viz.

	Yards Lineal.	Yards Superficial.
Regent Street and Waterloo Place, from Oxford Street to Pall Mall -	1300	24,401
Whitehall, from Buckingham Court to Richmond Terrace - - -	450	11,651
Margaret Street and Old and New Palace Yards - - -	260	9,199
	2010	45,251

(Signed) A. M. Robertson,
Clerk to the Commissioners for carrying into execution the Acts 5 Geo. IV. c. 100. and 6 Geo. IV. c. 38.

Office of Woods, &c.
30th April, 1827.

The following is a copy of a statement which appeared in a London Morning Paper on this subject:—

"*Macadamisation.*

"In the proceedings taken before the House of Lords, on the 11th of last May, several witnesses gave evidence on the Westminster Improvement Bill as to the comparative expense of macadamising and paving. According to this evidence, there is no less a difference in ten years than 2*l.* on every superficial yard; a yard of

paving for that time amounting to 10*s*. 10*d*., and a yard of macadamised road for the same period costing 2*l*. 10*s*. 10*d*.

"Mr. Johnson, an eminent pavior and stone merchant, stated before their Lordships that he had been a contractor for St. George's, St. Ann's, St. Giles's, and other parishes, and for some parts of the city, which enabled him to make very accurate calculations. He proved that the very best pavement would cost 13*s*. per square yard, which would require no repair for the first year certainly, and, in most cases, would cost nothing in repair for the first three years; that the expense after the first year would be about 4*d*. per yard per annum for ten years, after which the pavement as laid down would be worth 8*s*. per yard to the parish; thereby reducing the expense of a square yard of pavement in ten years to 10*s*. 10*d*., as under: —

	s.	*d.*
First cost, per superficial yard -	13	0
Ten years' repairs, at 4*d*. do. -	3	4
Ditto cleansing at 3*d*. - -	2	6
	18	10
Deduct value of old stone - -	8	0
Per yard - -	10	10

"The old stone might last twenty years longer; but, at all events, would be worth 8*s.* per yard after ten years' wear. That statement was made on a calculation of using the very best material; but most of the pavement is laid down at from 7*s.* to 10*s.* per yard.

"A macadamised, or broken stone road, requires for keeping in repair the first year, and every year after, two coats of three inches thick, to allow for wear: the coating costs 1*s.* 9*d.* each yard; the cleansing and scraping cost 10*d.* each yard, as under:—

	£	*s.*	*d.*
First cost, per superficial yard -	0	7	6
Two coatings, at 1*s.* 9*d.* each per yard, for ten years - - -	1	15	0
Cleansing, at 10*d.* per yard, for ten years - - - -	0	8	4
Per yard -	2	10	10

"The surveyor to the Commissioners of Westminster Bridge stated that the expense of paving and keeping in repair the bridge for twenty-two years (from 1802 to 1824) was 3494*l.*, including 1165*l.* for new pavement

in the first year, making an annual expense of 159*l.* About two years ago the bridge was macadamized, and the year after cost 1507*l.* 12*s.* 6*d.* There was a covering ordered in June, 1825, which cost 172*l.* 10*s.*, besides Mr. M'Adam's annual charge of 300*l.* The surveyor said, he thought it now required another covering like that of last year, at the expense of 470*l.* 10*s.*, as he had examined the road, and found the broken stones, on an average, not more than three inches thick."

The following is also taken from a London paper, and shows what was the result of converting the pavement over Blackfriars' Bridge into a broken stone roadway: —

Blackfriars' Bridge.

"The report presented to the Court of Common Council, last week, from the General Purpose Committee, relative to Blackfriars' Bridge, stated, that the City Surveyor having declared Mr. M'Adam had completed his contract for macadamizing the same, the Committee had subsequently employed him to keep the bridge in repair, and that he had since delivered in a bill to them for no less than 473*l.* odd, for such repairs, during a period of only eighteen weeks.

The Committee further stated, they had advertised for tenders to keep the said bridge in repair for twelve months, and several offers had been made them; one offering to do the same at between 300*l.* and 400*l.*, while a second tender was so high as 900*l.* In fact, it appears that the traffic over this bridge, which has greatly increased since it has been macadamized, is now to that amazing extent, that the new granite is ground to powder almost as quickly as it is laid down. It being thus evident that, to keep it in a proper state, the bridge would cost 1000*l.* per annum, and the City having no separate funds for that purpose, the Committee recommended that it should be repaved on its present surface, on an estimated cost of 1500*l.* The expense of keeping which in repair used to average under 120*l.* per annum. The report further stated, that Mr. M'Adam offered, at the time of the alteration being effected, to keep the bridge in repair for 130*l.* per annum."

ROADS PARTLY PAVED AND PARTLY MADE WITH BROKEN STONES.

To make a road of this kind, sixteen feet of the middle should be perfectly well paved, according to the rules already laid down, and the

remainder of it on each side of the pavement should be made with small broken stones. The advantages that would be derived from such a road would be — 1st, the saving of the labour of horses, as before explained in treating of pavements; and, 2dly, the diminishing of the expense of repairs.

If a road of this description be constructed with good materials, and in a workmanlike manner, it will require but a moderate expense to maintain it in excellent order; but constant attention will be necessary to keep the part where the pavement and the broken stones join from being cut into ruts.

Whenever the traffic of a road is so great as to wear down three inches of hard broken stones in a year, the middle part of it should be paved. At this rate of wear half a cubic yard of materials will be requisite for every lineal yard of eighteen feet of the breadth of the road.

This will make the expense of new stones alone, for a road thirty-six feet wide, per mile per annum, (supposing the cubic yard of broken stones to cost twelve shillings,) amount to 1056*l.* If the middle twenty feet of the broken-stone streets in London, where the traffic is

very great, were paved, a great expense would be saved; at the same time that the convenience of broken-stone roadways would not be taken away.

The following remarks of Mr. Telford on roads paved in the middle are taken from his first Annual Report on the Holyhead Road, dated 6th May, 1824, p. 7.: —

"As there is an ascent the whole way from London to the Archway road, it is particularly desirable to have the road surface as hard as possible. Flints are much too weak. What has been done for improving the Kensington road suggests a proper remedy, and the complete success of this experiment fully justifies the same plan being adopted on this Trust. I am fully aware of the strong prejudice against paved roads; but these prejudices have been created by the total want of skill in paving the streets of London, and their present very imperfect state. But if the middle sixteen feet in breadth of the present road were made use of as a foundation for a well-constructed pavement of stones of a moderate size, and of a cubical shape, with full square joints, no road would be fitter for heavy loaded carriages: the rough faces of the stones give a degree of action to the springs that eases

the draft, while the perfect hardness permits carriages to move forward with a slight exertion by the horses. Along each side of the middle part there may be a roadway, twelve feet in width, made with broken stones of a durable quality. These side roads would answer for the lighter description of carriages and riding-horses. The whole breadth of the road, exclusive of footpaths, would, according to this plan, be forty feet. This appears to combine all the requisites for roads in the vicinity of a great city." (See Plate III., Fig. 2.)

A ROAD WITH A FOUNDATION OF PAVEMENT AND A SURFACE OF BROKEN STONES.

The following specification of the manner of constructing a road of this kind of thirty feet in width, is taken from a contract for making a part of the Holyhead Road: —

"Upon the level bed prepared for the road materials, a bottom course or layer of stones is to be set by hand in form of a close firm pavement: the stones set in the middle of the road are to be seven inches in depth; at nine feet from the centre, five inches; at twelve from the

centre, four inches; and at fifteen feet, three inches. They are to be set on their broadest edges lengthwise across the road, and the breadth of the upper edge is not to exceed four inches in any case. All the irregularities of the upper part of the said pavement are to be broken off by the hammer, and all the interstices to be filled with stone chips firmly wedged or packed by hand with a light hammer; so that when the whole pavement is finished, there shall be a convexity of four inches in the breadth of fifteen feet from the centre.

"The middle eighteen feet of pavement is to be coated with hard stones to the depth of six inches. Four of these six inches to be first put on, and worked in by carriages and horses; care being taken to rake in the ruts until the surface becomes firm and consolidated, after which the remaining two inches are to be put on.

"The whole of this stone is to be broken into pieces as nearly cubical as possible, so that the largest piece, in its longest dimensions, may pass through a ring of two inches and a half inside diameter. The paved spaces on each side of the eighteen middle feet are to be coated with broken stones, or well-cleansed strong gravel, up to the footpath or other boundary of the road, so

as to make the whole convexity of the road six inches from the centre to the sides of it; and the whole of the materials are to be covered with a binding of an inch and a half in depth of good gravel, free from clay or earth." (See Plate III., Fig. 3.)

The work of setting the paving stones must be executed with the greatest care, and strictly according to the foregoing directions, or otherwise the stones will become loose, and in time may work up to the surface of the road: when the work is properly executed, no stone can move.

If the work be executed by contract, the inspector should see all the operations as they are going on. He should walk over the pavement when it is completed, and try whether the stones be firmly fixed: and he should not allow any broken stones to be laid on over the pavement till it has undergone an examination of this kind.

In breaking stones, the workmen should be required to break them as nearly cubical as possible. When this rule is not attended to, a great quantity of materials is wasted by first splitting the stones into thin slices, and then breaking them into pieces that are too small, and too thin. If the stones or top metal are not broken very

small, the proper degree of smoothness of surface will not be obtained.

When stones are very hard, they never make a very smooth surface. Limestone will make a much smoother surface than whinstone and other harder stones, but they should not for this reason be preferred to harder stones; for these will wear longest, carriages will run lighter over them, and the expense for scraping and repairing will be less. All the soft kinds of stones make heavy roads in wet weather; and in dry weather there will be more friction upon roads made with them, because there will be more dust on their surface.

The breadth of the road which has been described in the foregoing specification of thirty feet, is recommended as fully sufficient for any road, except a road forming the approach to a very populous city. The confining of a road to this breadth contributes very much to preserve the whole surface of it, from side to side, in a good state, and to diminish expense. For when a road is of greater breadth, the scraping and repairing of the excess beyond thirty feet costs annually a considerable sum. Mr. Telford says on this point, in his second Annual Report on the Holyhead Road, dated 17th June, 1825: —
"He" (the surveyor of the Stonebridge and

Birmingham Road) "seems to be still too much disposed to prefer a road of a greater breadth than that recommended by me, of thirty feet: he should reflect, that every yard in breadth makes 1760 superficial yards to be kept in good order in a mile, and therefore that a road of thirty-nine feet wide has 5280 superficial yards to be coated with materials, and kept clean, more than a road of thirty feet wide. The additional expense of the wider road may be set down at 15*l.* a mile, and this rate for ten miles will make on his road an extra expenditure of 150*l.* a year."*

With respect to the convexity of a road, it should be so arranged that it should be slight in the middle. In giving a convexity of six inches to a road of thirty feet in breadth, the convexity at four feet from the centre should be half an inch; at nine feet, two inches; and at fifteen feet, six inches. This will give the form of a flat ellipsis.

The binding, which in the foregoing specification is required to be laid on a new made road, is by no means of use to the road, but, on the contrary, injurious to it. It is, however, unavoidable, when a long piece of new road is to be opened; for, without it, the wheels,

by sinking into the new materials, would make the draught of the carriages much too heavy for the horses. This binding, by sinking between the stones, diminishes the absolute solidity of the surface of the road, lets in water and frost, and contributes to prevent the complete consolidation of the mass of broken stones.

If the plan here laid down for constructing a road be faithfully executed, it will secure all the objects that can be required. From the moment it is first opened, it becomes daily harder and smoother, and very soon consolidates into as hard a mass as can be obtained by the use of broken stones. The subsoil of the road cannot get into a state of puddle, and rise up and mix with the surface materials, and thus produce those quagmires and deep ruts that are met with in wet weather on new roads made in the usual way.

Although the expense of constructing a road on this plan may seem to be greater than that of making a road in the usual manner, taking on an average of five years, the joint expense of constructing and repairing such a road as the former, it will be much less than that of constructing and repairing a road made by putting the surface materials on the natural soil, without a paved foundation; for, in point of fact, such a

road has usually to be nearly new made every year, for some years after it is first opened.

This method of making roads with a foundation of pavement is described in French works on roads; the following is taken from the *Encyclopédie de l'Ingénieur*, vol. i. page 356.: —

"The first course of stones are to be from ten to twelve inches long, and nine inches deep. These are to be set by the hand on the bed of the road, with their broadest faces down and their pointed ends upwards; the interstices are to be filled with stone chips. The upper course of stones is to be of the hardest kind, broken to the size of an inch cube, on a large stone, as an anvil.

"This course is to be nine inches in thickness, so that the whole thickness of the two courses will be eighteen inches." *

The bed of pavement, for the whole width of the road, may, in some instances, be too

* Since the sheet containing a note on the Simplon road has been printed off, the author has met with a reply to the *Mémoire* of M. Ceard, by M. C——, the engineer alluded to, which seems to exculpate M. C—— from the charges made against him.

For a full description of this road, so deservedly celebrated as one of the most magnificent of Napoleon's works, see *Monumens, Victoires et Conquêtes des Français, de* 1792 *à* 1815, par M. Ch. Dupin.

expensive, in consequence of the difficulty of procuring proper stone.

In such instances, it may be expedient to have only the eighteen middle feet of the carriage way with a foundation of pavement. (See Plate III., fig. 4.)

In a district of country where any coarse sort of stone can be got for making a pavement, it will be cheaper to make a road with a pavement and six inches of broken stones, than with ten inches of broken stones without a pavement.

The following observations on the expediency of making a paved foundation for a road is taken from a Report of Mr. W. A. Provis, assistant engineer to Mr. Telford, under whose immediate direction all the works on the Holyhead Road, in North Wales, were constructed: —

"The pitching or paving the bottom of a road is a subject which has often been discussed, and, though generally approved of by scientific men, has met with some decided opponents.

"On the old part of the Shrewsbury and Holyhead Road, which extends from Gobowen to Oswestry, as well as in some other places, the foundation of the road had been paved, but in

an irregular and promiscuous manner, some of the stones standing near a foot above others, and in some places holes were left without any stones; upon this a coat of gravel had been laid, and necessarily of very unequal thickness, some of the points of the stones being scarcely covered.

"This road having afterwards been much neglected, the upper gravel, where thin, was worn quite away, or else forced from its bed by being in so thin a coat that it could not bind, and the road's surface was thereby made a continued succession of hard lumps and hollows with water standing in every hole after a shower, and no means of getting off but by soaking through the road.

"Any stranger, on passing over such a road, would condemn the principle on which it was made. But here seems to be the great error,—that the principle is condemned, instead of the abuse of it. When the paving is put down carefully by hand of equal or regular height, with no large smooth-faced stones for the upper stratum to slide upon, and the whole pinned so that no stone can move, I have no hesitation in saying that in many cases it is highly beneficial, and in none detrimental. Whenever the natural soil is clay, or retentive of water, the pavement acts

as an under drain to carry off any water that may pass through the surface of the road. The component stones of the pavement, having broader bases to stand upon than those that are broken small, are not so liable to be pressed into the earth below, particularly where the soil is soft. The expense of setting this pavement is less than one fourth of that of breaking an equal depth of stones to the size generally used for upper coating; and therefore, in point of economy, it has also a material advantage.

"Mr. Telford, in all cases recommends this paving; and the opinion of a man of such experience cannot be treated slightly. He has made more miles of new road than any engineer in the kingdom; and having myself studied for nearly fifteen years in his school, and made a considerable extent of road under his direction, I may venture to say that his practice is not unsupported by experience.

"I should not have said so much on this subject, but from the circumstance of other road improvers having asserted that paving was useless; and I think that assertions on one side should be met with firmness on the other, whenever an important principle is attacked, the correctness of which can be established by reasoning and by facts.

"Whenever any new piece of road has been made, I have taken care that a good bottoming should first be put under the broken stones, because I am satisfied that it makes the road more substantial, and is also less expensive. Some of the new road made on this principle by the Commissioners under the Act of 55 Geo. III. has now been travelled upon for four years; and its present perfect state, I have no doubt, is owing to the firm foundation which was laid under the broken stones. I must refer to my last Report for further particulars of its advantage; but as I did not then notice the comparative expense of the two modes of road-making, it is proper to state it here, in order to justify the course I have adopted.

"Supposing the materials are stone, to be quarried, and carted, say, a quarter of a mile on an average; that the stoning shall be in both cases sixteen feet wide; that, by Mr. Telford's mode, the bottoming shall be seven inches thick in the middle, and five inches at the sides, and the broken stones six inches in uniform thickness; and that by the other mode there shall be no bottoming, but ten inches in depth of broken stones.

"The expense of a lineal yard on Mr. Telford's principle will be as follows: —

	s.	d.
Quarrying $1\frac{3}{4}$ cubic yards of stone (measured on the road) at 1*s.* 8*d.* - -	2	11
Carrying $1\frac{3}{4}$ ditto — $\frac{1}{4}$ mile on an average — at 6*d.* - - - -	0	$10\frac{1}{2}$
Setting the bottom - - -	0	2
Breaking the top 6 inches $\frac{8}{9}$ cube yard at 1*s.* 6*d.* - - - -	1	4
	5	$3\frac{1}{2}$

"The expense of a lineal yard without bottoming would be —

	s.	d.
Quarrying and carrying $\frac{5}{6}$ of the above quantity of $1\frac{3}{4}$ cubic yards of stone -	3	2
Breaking 10 inches in depth $1\frac{1}{2}$ yards at 1*s.* 6*d.* - - - -	2	3
	5	5

"But if there were plenty of loose stones to be had without quarrying, which is very often the

case, the expense per yard, with bottoming, would be,—

	s.	d.
Carriage of $1\frac{3}{4}$ cubic yards - -	0	$10\frac{1}{2}$
Setting the bottom and breaking the top as before - - - -	1	6
	2	$4\frac{1}{2}$

"Without the bottoming it would be—

	s.	d.
Carriage of $\frac{5}{8}$, the last-mentioned quantity - - - -	0	$8\frac{1}{2}$
Breaking 10 inches as before - -	2	3
	2	$11\frac{1}{2}$

"The first of these cases shows a saving of $1\frac{1}{2}d.$, and the latter of $7d.$ per lineal yard in favour of the bottomed road, a saving which of itself would not weigh much; but, as the bottomed road is the most substantial and durable, it adds one more to its other advantages." *

* The following are extracts from Mr. Telford's first Annual Report on the Holyhead Road, May 1824; and from his sixth Annual Report, May 23. 1826:—

"Besides the advantages of easy inclinations, ample

We shall conclude our remarks on the necessity of providing a proper foundation for a road by giving a description of the new Highgate

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breadth, perfect drainings, and complete protection, the forming of a smooth hard surface is one of the distinguishing characteristics of this new road. In summer it is not dusty, and in winter it is very seldom dirty; frosts and rains produce but trifling and superficial effects upon it. During the unusually severe frosts of the winter 1822—1823, and the subsequent thaws and heavy rains, the new road was not cut up or rutted in a single instance, though in several parts of the old road, even where it had been put into decent repair, it was too weak to stand such hard tests: it broke up and became as bad as a bog. This breaking-up was not confined to parts of the Holyhead road, but was the case, and to a much greater extent on many, and perhaps all the roads of the neighbourhood. In fact it seemed to be almost universally the case on all roads not constructed with strong foundations, and particularly where the substratum was clayey and retentive of water.

"The great superiority which the Holyhead new road evinced at that trying time, was doubtless owing to the substantial foundation which had been prepared for it, previous to the upper stratum of broken stones being laid on it. This foundation is a regular close pavement of stones, carefully set by hand, and varying in height from eight to six inches, to suit the curvature of the road; these stones are all set on edge, but with the flat one lowest, so that each shall rest perfectly firm. The interstices are then pinned with small stones; and care is taken that no stone shall be broader than four or five inches, as the upper stratum does not bind upon them so well when they much exceed that breadth. The pavement thus constructed is quite firm and immovable, and forms a complete separation between the top stratum of

Archway Road, made with a foundation composed of Roman cement and gravel.

This road, of little more than a mile and a

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broken stones, and the retentive soil below. Any water which may percolate through the surface, is received amongst the stones of the pavement, and runs from them into the next leading, or cross drain, and there escapes. Was there no pavement, the water must remain among the working materials of the road, or rest on the surface of the clay till again evaporated. Should frost succeed, the pavement prevents its acting on the clay, as the water has previously escaped; and as hard stone is not perceptibly altered by frost, it consequently can produce no effect on the surface. Where the water cannot escape, or when, from a want of the intermediate pavement, the frost reaches the clay, which always contains a considerable quantity of moisture; then that moisture or water is expanded by the operation of freezing, and heaves up the whole of the road. A subsequent thaw allows it to subside, but the connection between its parts being disturbed and broken, and the materials loosened, the first heavy weight that passes over them will go quite through, if only of moderate depth; or cut them into ruts when the depth is great. The substratum too is reduced to a semi-fluid state, and by the pressure of the hard materials and heavy weights, it is forced to the surface as the only means of escaping. If it is attempted to scrape this dirt away directly afterwards, much of the stone or gravel will unavoidably be mixed with it, and also removed. Whilst it remains, the road is scarcely better to travel over than a ploughed field; and when removed, a hole is left on the surface."

Extract from the sixth Report. — "In order to ascertain the most effectual mode of rendering the driving-way hard

half in length, was originally made by a private company, at a great expense, owing to the nature

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and smooth, I caused an experiment to be made along a quarter of a mile, at the northern extremity of this road (the Highgate Archway Road), by constructing the roadway with a bottoming of Parker's cement and gravel, and with a coat of Hartshill stone laid upon it; and to ascertain what would be the comparative effect of using the same stone on the old surface of the road, I had a large quantity of it laid on between the arch and the Holloway road. The result is, that between the months of October and March last, full four inches of the stone on the old road, between the arch and the Holloway road, was worn away, where eight inches had been laid on, while not one inch was worn down where it was laid on the cement bottoming. This result corresponds with other trials where bottoming has been made with rough stone pavement.

"The different parts of the Holyhead road which have been newly made with a strong bottoming of stone pavement, place beyond all question the advantage of this mode of construction; the strength and hardness of the surface admit of carriages being drawn over it with the least possible distress to horses. The surface materials, by being on a dry bed, and not mixed with the sub-soil, become perfectly fastened together in a solid mass, and receive no other injury by carriages passing over them than the mere perpendicular pressure of the wheels; whereas, when the materials lie on earth, the earth that necessarily mixes with them is affected by wet and frost, the mass is always more or less loose, and the passing of carriages produces motion among all the pieces of stone; which, causing their rubbing together, wears them on all sides, and hence the more rapid decay of them when thus laid on earth, than when laid on a bottoming of rough stone pavement. As the materials wear out less rapidly on such a road, the expense of keeping it in repair is

of the sub-soil, which consisted of sand, clay, and gravel. A tunnel was in the first instance attempted to be driven through the hill, which, after having been executed for a considerable length, fell in; the brickwork not being sufficiently strong to withstand the pressure of the clay and sand acting against it. After the failure of the tunnel that scheme was abandoned, and open cutting was resorted to.

The road-way was formed by laying on the natural soil a very large quantity of gravel and sand as a foundation, and this was covered, to a considerable depth, with broken flints and larger gravel. The carriage-way, however, notwithstanding this quantity of materials, was so heavy, loose, and difficult to draw over, that many carriages and waggons continued to go over the old steep road, and the company in consequence received little or no return for the capital they had expended in the work. This induced them to try every expedient they could devise, to improve the condition of the road, but without success. One of the schemes resorted to was,

proportionally reduced. The expense of scraping and removing the drift is not only diminished, but with Hartshill stone, Guernsey granite, or other stone equally hard, is nearly altogether avoided."

to take up all the road materials, and cover the subsoil with pieces of waste tin, over which gravel, flints, and broken stones were placed. All this, however, was of little or no use: the road continued imperfect, and even dangerous for fast coaches; the consequence was, that the Parliamentary Commissioners received complaints and petitions from coach-masters, and other persons who had occasion to work horses over this road, praying that they would cause an examination into the state of the road, and have the defects remedied.

In consequence of these petitions, a Select Committee of the House of Commons, in the year 1817, examined several witnesses upon the state of the road, and, amongst others, a director of the Company, Mr. Hoggart, who stated, that the annual expense of keeping the road in repair was 420*l.*

Notwithstanding the investigation which then took place, the road, as may be seen from Mr. Telford's Annual Reports to the Parliamentary Commissioners, still continued in a very bad and imperfect condition.

In 1829, the Parliamentary Commissioners made an arrangement with the Highgate Archway Company, for taking the road under their management, and for borrowing from the Trea-

sury a sum of money to put it into complete repair. In order to accomplish this, several experiments were tried by draining the surface and subsoil, and by laying on a thick coating of broken granite; but from the wet and elastic nature of the subsoil, the hardest stones were rapidly worn away by the wheels of carriages, but much more by the friction of the stones themselves against each other; for, in a very short time, they were found to become as round and as smooth as gravel pebbles, even at the bottom of the whole mass of road materials; it was therefore evident, that to form a perfect road, which might be kept in repair at a moderate expense, it was necessary to establish a dry and solid foundation for the surface broken stones; but as no stones could be obtained for making a foundation of pavement but at a very great expense, a composition of Roman cement and gravel was suggested by Mr. M'Neill, and this, on trial, was found to answer effectually. The manner of laying down this cemented mass, and constructing the road, is fully detailed in the following evidence, given by Mr. M'Neill before a Select Committee of the House of Commons, in May, 1830: —

"Are you the resident engineer under Mr. Telford, on the road from London to Shrewsbury? — Yes.

"You conducted the work at the Highgate Archway road? — I did.

"Will you explain to the Committee the expense of the cement composition which was laid on the foundation? — The expense of the cement delivered was 2*s*. a bushel; it was mixed with eight times as much of washed gravel and sand.

"What distance of ground would a bushel so made extend? — Laying on the cement six yards wide and six inches in thickness, came to 10*s*. a running yard; but in this case part of the gravel got in taking up the old road, was used; if new gravel had been purchased, it would have cost from 12*s*. to 15*s*.: that included the forming the bed of the road, which was done with very great care. There were four drains formed longitudinally, and there were secondary drains running from those to the side channel drains, and those again to drains outside the footpaths, covered with brick, and they all communicated with each other, and discharged the water into proper outlets. On the prepared centre of six yards in width, after it had been properly levelled, the cement was laid on, mixing it first in a box, with water, gravel, and sand, in certain proportions: every cask of cement was tried before it was allowed to be used, and when we

found it set properly, in about fifteen minutes, we then used it.

"Did it become hard in fifteen minutes? — Yes, so that we could stand upon it: in about four minutes after being laid, a triangular piece of wood, sheeted with iron, was indented into it, so as to leave a track or channel at every four inches for the broken stones to lie and fasten in.

"For grooves for the stones to bed in? — Yes; and this triangular indent had an inclination of full two inches from the centre to the sides; so that if water came through the broken stones, it ran off the cemented mass into the longitudinal drains.

"The cement had that fall from the centre of the road? — Yes, three inches from the centre to each side; that was sufficient to allow the water that percolated through the broken stones to run off.

"What time of year was this composition laid on the road? — 200 yards was done in winter; all the rest in July, August, and September.

"It has been on the road through the last winter? — There has been part of it on since June, 1828, nearly two years.

"Have you examined it to see what effect the weather has had on it? — I examined it frequently during the frost, almost every six

weeks, and I never came to town without examining it.

"In what state have you found it?—Perfectly hard in every case.

"Not injured by the frost nor the working of the carriages over it?—Not in the least: there was an injury of six feet square, but it originated from the side banks of the road coming down and bulging it up.

"By under-pressure?—Yes; only six feet square was injured.

"At what rate of expense can a square yard be laid, six inches thick, of this composition? In the neighbourhood of London it could be laid for about two shillings, according to the locality, per yard six inches thick.

"Was it dearer at Highgate, at the Archway Road?—About twopence dearer than it would in London.

"How many yards wide was it laid?—Six yards wide: the gravel that was found in the road was made use of for part of it; if it had to be purchased, it would have cost 2*s.* to 2*s.* 6*d.*

"What state was the road in when it was given into your possession by the Company?—I think it was as bad a road as I ever saw; a coachman could hardly sit on the box when driving along it.

"Was it in consequence of the surface being

so uneven?—The surface was uneven in some places; it was not in ruts, but in holes several inches deep.

"What was the surface composed of?—Principally clay, gravel, and sand.

"No body of strong materials?—They could not last on it; they were worn out: an immense quantity had been put on; there were 1200 cube yards of gravel put on annually. Shortly before we took possession of the road, they put about 800*l.* worth of granite on a small space; the directors said it was necessary to examine the quantity of granite in the road, that we might deduct it from the contractor's prices, as they had laid out 800*l.* in so short a time; I did in consequence examine it, and opened the road in various places, particularly where they told me it was on, and I could hardly find a stone of it.

"Were not some of the stones worn into a perfect round shape?—Almost every one I found was as round as an egg.

"What, in your opinion, was the cause of these materials wearing out so rapidly?—From the rubbing against each other, and from the weakness of the surface, and the elasticity of the road; in all cases those round stones were at the bottom.

"Was the road damp and wet?—Very wet.

" Had those stones worked themselves down below the furze and tin you say you had to remove?—They were resting on them, and they were quite elastic.

" Can you state to the Committee how many tons of gravel and stone have been laid on the road since it has been put under the care of the Commissioners? — Eight thousand one hundred and forty-six tons of gravel, and 3614 tons of granite.

" Can you state the number of yards of drains that have been made? — There have been four longitudinal drains made the whole length of the road, besides numerous cross drains, one at every thirty yards; and there have been intermediate small drains every ten yards under the cement; making in all, 12,803 yards.

" What was the reason for making such an unusual quantity of drains? — From the nature of the ground: it was cut through a clay soil, high banks on each side; and all the surface water that came from the slopes and Highgate Hill, came down and rested in the hollows of the subsoil.

" You made use of the cement because you could get no stone to make a pavement? — That was one cause; in that situation it was both better and cheaper than any stone.

" Can you give the Committee any statement

of the comparative expense of keeping the road in repair, previous to the undertaking of the work by Mr. Telford, and since? — Yes, I can; I understand it cost 900*l.* a year; it can now be kept in good repair for much less.

"Have you an opportunity of explaining to the Committee the different degree in which the hard stone wears where laid on the surface of such a road as that was, or laid upon a cement foundation? — Yes, I have; I have tried it repeatedly since the stone has been laid on.

"How many inches did you find of the stone wear out which was first laid on the road before the cement bottoming? — I found four inches gone in one place where it was not on the bottoming, and not half an inch where the bottoming was; the same stone, quartz, was used in each experiment.

"You made the experiment on purpose? — Mr. Telford desired the experiment to be made.

"So that you can state without any risk of error and mistake? — Quite certain; because it was on that the last contract was founded of carrying the work into execution.

"Have you any notion of the saving of horse labour in consequence of the improvement of the road? — I have. I have tried the draught of drawing a waggon over it by the instrument I

have invented, and which has been approved of, and ordered by the Commissioners to be used on the Holyhead Road for proving the comparative merit of each part of the road; and I found that it took a power of 56 lbs. on the Archway Road; and I have no doubt whatever that if it had been tried in the first instance, before the improvement was made, that what is now 56 lbs. would have been at least 156 lbs., judging from trials made on roads equally bad; or that fifty-six horses will now do as much work as 156 could before the road was improved.

"Before you were employed by the Parliamentary Commissioners, were you employed in making and repairing roads on the system of putting the broken stone on the soil, or on the surface of the old roads? — Yes, since 1816.

"You have now an opportunity of judging of the comparative wear of materials, whether so made use of, or put on a paved foundation: will you describe to the Committee what, in your opinion, is the general result? — I have attended to it very particularly, and I have no hesitation in saying, that the annual saving from a paved bottom will be one third the expense in any case; either a stone or cement bottom is the same; it is merely the solidity and dryness that is required.

"In your experience and the observations you have made, taking together the first expense of making a road in the ordinary way, by putting the broken stone on the soil, and taking a certain number of years' subsequent expense, say ten years, and on the other hand, taking the first expense in making a road with a solid foundation, either of stone or cement, with the same sort of broken materials and surface, for the same period of time, which would you say would be the cheapest in the end? — There can be no doubt at all upon that subject: the saving, I think, will be one third, and if you include the labour of horse power that is gained, it will be very considerably more than that.

"In favour of which? — In favour of the paved bottom.

"What would be the saving in the course of ten years in favour of the paved bottom? — The saving in ten years will depend on local circumstances, but in every case a paved bottom will be found the cheapest: in the first place the breaking of the stone is saved, which, where hard granite is used, is considerable; in the second place, a softer, weaker, and generally a cheaper stone than can be used for the top material may be made use of for the pavement; thirdly, the surface stones are preserved from wear in an

extraordinary manner, by resting on a solid firm foundation, instead of mixing with the wet sub-soils, and forming a loose elastic road, which takes some years, and wears out many materials, before it becomes hard and solid.

"What do you mean to express by a paved bottom? — Unbroken stone set on edge across the road, six or eight inches deep, and three or four inches thick; set firmly side by side, and the interstices filled up with stone chips packed in with a small hammer.

"This forms, in point of fact, a regular pavement, but not smooth on the surface, of about seven inches deep, as the road foundation. Five inches at the side, and seven inches in the centre, if the pavement is eighteen feet wide.

"What kind of stone do you use for this purpose?—Sandstone, limestone, or schistus, or such as can be had in the neighbourhood; any stone, almost, will answer that will bear weight and not decompose by the atmosphere.

"Is it not, in many instances, cheaper than any other material you can use? — It is the cheapest in the first instance, because you have not to break the stone; and the subsequent repairs cost less."

Some time after the road was improved as above described, the contractor of the work

wrote a circular letter to some of the principal coachmasters and coachmen; requesting to have their opinion of the state of the road.

The following are extracts from some of the answers to those letters, as published in the Appendix to the Report of the Select Committee, on the Holyhead and Liverpool Road, printed 30th May, 1830:—

"Golden Cross, Charing-cross, 10th May, 1830.

"Sir,

"In answer to your letter, dated the 1st instant, respecting the present state of the Highgate Archway road, I have to remark, that it is most surprisingly improved since you have adopted the plan of Mr. Telford; in fact, so much so, that *four horses* can better perform their journey now (both as regards speed and ease), than *six horses* could do previous to such plan being adopted. And although the weather, this year, has been much against the roads; notwithstanding that, your much improved plan has well contended against such weather; so much so, that I have not had occasion to require six horses at any time during the last winter, although in various other places I could not possibly proceed unless I employed that number of horses; for instance, from Barnet to Colney, near Ridge

Hill, I have constantly gone with six horses, and even then with difficulty.

"B. W. HORNE."

"Sir,

"In reply to your letter, I have to state to you the wonderful improvement made on the Archway road. The short time since its completion, and the severe winter it had to encounter, proves beyond doubt the complete success of of the plan. Since my commencement in driving on the Birmingham road, it was with difficulty I could get up the Archway Hill, on one side or the other, with *six horses*, but now *four middling horses* are sufficient for any of our loads.

"THOMAS BRAMBLE."

"Lawrence-lane, 15th May.

"Sir,

"In reply to yours of the 4th instant, requesting my opinion respecting the late improvement of the Highgate Archway road, it is with sincere pleasure I am enabled to state, that, during the whole course of my experience, I never saw so much improvement in so short a period: in fact, from its being the very worst piece of road between London and Manchester,

it is now become, through your exertions, decidedly the best. I was fearful the severe winter we have experienced, setting in so very soon after its being completed, would have broken it up; but I am most happy to say that, during the whole winter, I have not observed a single place where it was the least affected. Previous to this winter, it was all we could do to walk up both sides of the Archway with six horses, and now we can trot up with our heaviest loads with four.

"When I first commenced driving on the above road, we were obliged to keep twelve horses to work a slow coach to Barnet, and now we can work a fast one the same distance with ten horses.

"I think the facts above stated are at once a convincing proof of the full success of the plan you have adopted; and, as one individual concerned, I beg leave to offer you my most sincere congratulations thereon.

"CYRUS J. COATSWORTH."

ROADS MADE WITH A FOUNDATION OF RUBBLE STONES, AND A SURFACE OF BROKEN STONES.

A useful road may be constructed by making a foundation with rubble stones, and laying broken stones or gravel upon them.

The stones should be reduced so as not to have any of them more than four pounds in weight; these should be laid in a regular bed, to the depth of seven inches in the middle and four inches at the sides, supposing the road to be thirty feet in breadth; a coating of small broken stones should then be laid on in the way directed when a pavement is used.

If the subsoil be clay, a course of earth, of any kind, that is not clay, of the thickness of six inches, should be laid upon the clay, to prevent it from rising and mixing with the stones.

A road made according to the rules here given will not be a very expensive one: it will answer for cross turnpike roads, and other roads that do not communicate between large towns and collieries.

This plan is much superior to, and not more expensive than, the next plan.

A ROAD MADE WHOLLY OF BROKEN STONE.

A road may be constructed, suitable to light carriages and little traffic, by forming a level bed on the natural soil, and putting upon it a body of broken stones, of twelve inches in thickness in the middle, and six at the sides. The stones

should be laid on in successive layers, taking care to let each layer be worked in, and consolidated, before a fresh one be laid on. If the subsoil is clay, a course of earth should be laid upon it, as proposed in the last plan.

Roads of this description are not sufficiently strong for great thoroughfares. This plan, however, having of late been recommended, as greatly superior to all other plans, by persons who profess to be experienced and scientific road-makers, a number of turnpike trustees have adopted it; but experience has fully established its unfitness for roads of great traffic, in comparison with roads made with a proper foundation. In point of fact, there is nothing new in this plan; for all the roads of the kingdom have been made in this way, and the universal defect of them, namely, their weakness, is the result. The reason is very obvious; for if a body of small broken stones be laid on the natural soil, the weight of carriage wheels passing over it forces the lower course of the stones into the soil, while the soil is forced up into the interstices between them; the clean body of stones, first laid on to make the road, is thus converted into a mixed body of stones and earth, and, consequently, the surface of the road cannot but be very imperfect as to hardness. It is necessarily heavy in wet weather, on ac-

count of the mud the earth makes on its surface; and, in dry weather, on account of a quantity of dry dirt.

A road made on this plan will require, for two or three years after it is said to be finished, the expending of large sums in new materials, to bring it into any thing like even an imperfectly consolidated state; and, after all that can be done, such a road will always run heavy, and break up after severe frosts; for, as the natural soil on which such a road is laid is always more or less damp and wet, it will necessarily keep the body of materials, of which the road is made, damp and wet; in consequence of which, the surface of the road will wear down quickly. Hard frosts will penetrate through the materials into the under soil, and, when thaws take place, break up the whole surface.

It is in this way that the ruinous state of most roads, after severe frosts, is to be accounted for.

ROADS MADE WITH GRAVEL.

In a country where no stone can be got for making a road, and nothing better than gravel can be procured, the following plan of employing it may be adopted: — When the bed of the

road has been formed, a coating of small gravel should be laid on, four inches thick, over the whole breadth of the road; carriages should then be let to run upon it, and the ruts should be raked in as soon as they appear. When the first coat of gravel has become tolerably firm, another coating, once screened, should be laid on, three inches thick, over the whole surface, and the ruts raked in as before. When this second coat of gravel is consolidated, a third should be laid on, three inches thick: this coat of gravel should be well riddled, and cleansed from all earth or clay, and all pebbles exceeding one inch and a half in diameter should be broken before they are laid on the road. This process should be repeated until there is a body of gravel laid on the road sixteen inches thick in the middle, and ten at the sides, so as to form a convex surface rising six inches from the sides to the centre. The strongest and best part of the gravel should be put on the middle fifteen feet of the road, and the small part of the gravel on the sides. In all gravel roads of this description the greatest care must be taken to drain the subsoil by a sufficient number of cross and mitre drains, communicating with the main drains. If this is not attended to, it will be impossible to form a good carriage way.

A road made with gravel in the way here recommended will be much stronger than gravel roads usually are; but it will be much inferior to one made with stone materials. The roundness of the gravel stones prevents them from becoming consolidated by pressure, so as to form a perfectly hard road surface; and when the gravel consists of limestone, flint, freestone, sandstone, or other kinds of weak stone, it is so rapidly pulverised that the friction produced by wheels passing over it, adds greatly to the labour of horses.

CHAP. VI.

FENCES.

In districts of country where stones are abundant, walls will be the best fences: they require less land than hedges; and, when they are properly built, they give a very neat and finished appearance to a road.

The manner of constructing these fence walls will be described in the chapter on road masonry. Where a quick fence is to be raised, the following specification points out every thing that is requisite: —

"A ditch is to be cut and a bank raised, together occupying a space of eight feet in breadth; the ditch is to be on the field side of the bank, to be cut out of the natural ground, four feet wide at top, ten inches wide at bottom, and two feet and a half deep.* The bank is to be four feet wide, and is to be raised by sods, with the green or swarded side out, to the height of fourteen inches above the side channels of the road.

* Where the soil is clay the drain should be four feet deep.

"Two rows of quicks are to be planted on the ditch side of the bank, a bed being first formed for them, of good vegetable mould, fifteen inches deep, and eighteen inches wide. There are to be twelve plants set in every lineal yard: they are to have good roots, three years transplanted from the quick bed, and of a strong and healthy appearance.

"These quicksets are to be protected by two rows of posts and rails; three rails in each row: the posts to be of good oak, five feet long, five inches deep by three inches wide, with large buts sunk two feet in the ground.

"The rails are not to be more than eight feet long; to be three inches and a half wide by an inch and a half deep, of good elm, oak, or ash timber.

"In each length of rails two centre posts, at least two inches wide by an inch and a half thick, are to be driven into the ground, and fastened to the rails with strong nails.

"Through cuttings instead of the ditch and mound as before described a mound is to be raised on each side for the quicks, eighteen inches high, two feet wide at top, and faced with sod on both sides; outlets for the water which collects behind the mound from the slopes are

to be formed under it, at intervals of twenty yards.

"The mound to be composed of the best vegetable mould that can be procured.

"The quicks are to be planted in the centre of this mound."

A quick fence may be also raised in the following manner, in dry soils, without any ditch:—

"A border or flat mound, four feet in width, is to be raised on each side of the road: it is to be six inches above the footpath, and twelve inches above the side channels of the road, if there is no footpath. The top of the mound next the fields is to be made with good earth two feet wide, and to the depth of fifteen inches: two rows of quicksets, twelve in each lineal yard, are to be set in the middle of these two feet."

"These quicksets are to be protected by two rows of posts and rails, as before described."

Where timber is scarce, quick fences may be raised in the following manner:—

"A ditch is to be cut five feet wide at top, and eighteen inches at bottom, and four feet deep, the sods where the land is grass to be laid two feet high above the side channels of the road, and the earth taken out of the ditch to be formed into a bank five feet wide, sloped to a breadth of

eighteen inches; to be four feet high; two rows of quicksets to be planted on the outward face of the bank towards the field, in the natural soil on the face of the bank."

When a road is formed on a high embankment, a fence may be made according to the following specification: —

"A wall is to be built on each side of the road thirty feet apart, eighteen inches thick at the foundation, and fifteen inches at the top, two feet high above the side channels, and nine inches deep below them; in all, two feet nine inches.

"The stones are to be laid in neat level courses, closely jointed and well bonded on both sides, and to be of a kind that will not decompose by the weather.

"The length of the top stones to be the thickness of the wall, viz. fifteen inches, and from five to six inches deep, to serve as a coping. A mound of earth twenty inches high is to be raised above the wall, with two lines of sods in the front. One row of quicksets, of twelve in each yard, to be planted on the mound. A single rail fence is to be made to protect the quicksets: the top of the rail is to be fourteen inches above the mound."

Whenever a road is carried through a deep

cutting walls should be built for the road fences, if stones can be procured.

Such a fence may be made according to the following specification: —

"Walls of dry stone masonry are to be built on each side of the road, thirty feet apart. They are to be three feet above the side channels of the road, and six or nine inches deep below it; they are to be twenty-four inches thick at the foundation, and fifteen inches at the top. They are to batter one inch in a yard on the side next the road, and seven inches and a half in the whole height on the other side. The coping-stones are to be not less than fifteen inches in length at top, to cover the whole thickness of the wall, and to be seven inches thick; neatly hammer-dressed, square-jointed, and set in mortar: the whole of the masonry to be laid in level beds, and well bonded."

All road fences should be kept as low as possible, in order that they may not intercept the sun and wind, and diminish their effect in producing evaporation.

For this reason, in deep cuttings, the quicks should never be planted at the top of the banks; but always low down, near the side of the road.

All quick hedges along the sides of roads

should be clipped every year in the months of August or September. They should be trimmed so as to be perfectly level at the top, and with a regular and even surface on the side next the road.

To ensure regularity in the appearance of the hedges, a line and templet should be made use of in trimming them.

CHAP. VII.

ROAD MASONRY.

In constructing roads, masonry is used in a great many cases, and too much pains cannot be taken to have it perfect both in plan and execution.

BRIDGES.

In arranging the plan of a bridge for a road, it should be considered how far it may be made subservient to improve the longitudinal inclination of a road, and save perpendicular height.

When valleys are deep and narrow, they may frequently be passed without great inclinations in the roadway, by selecting a proper position, and building high piers and arches for a bridge, if a stream or river is to be crossed, as is usually the case. On the other hand, when the land on each side of a river is flat, the bridge should be kept low, to avoid an inconvenient ascent to the top of it.

The following are the principal objects, with respect to bridges, which road-makers should have in view, viz.:—1st, the most eligible situation as regards the direction of the road; 2dly,

the proper width for the roadway; 3dly, the inclinations of the roadway over the bridge; and 4thly, the number and span of the arches.

The best situation for a bridge, as it respects a road, will evidently be that which preserves the most direct line: but, for the security of the bridge, it is desirable to have a straight reach above it, and no bend near it.

The width of a bridge between the parapets should be regulated by the nature and quantity of traffic that is to pass over it. On turnpike roads near large towns the width should be at least near forty feet. On turnpike roads in the country thirty or thirty-six feet will be sufficient, and on parish roads, twenty or twenty-four feet.

The inclinations of a road way over a bridge should be very moderate. On turnpike roads they should never exceed one in thirty where it is possible to avoid it, without incurring a great expense in filling for the approaches. The number and span of the arches must depend on various circumstances, which can only be taken into consideration by the engineer on the spot; and even then much more must be left to his experience and judgment than can be derived from any precise rules as to the proper number and size of the arches.

It will be sufficient to state that the main point to be attended to in every case is that the water way should be of ample dimensions, to allow the whole body of water to pass freely in the highest floods.

For this purpose the bridges below the site of the proposed bridge should be carefully measured, and the effects of floods upon them observed. This will be a good criterion for assisting in determining what the water way should be of the intended bridge.

In making a plan and estimate of the expense to be incurred in building a bridge, the most essential point to be fully examined and considered is the securing of such a foundation as will be sufficient to preserve the stability of the edifice. An engineer should make accurate borings, to ascertain the nature of the sub-soil; and when the slightest defect appears, piling should be used.

As the building of large bridges does not come within the scope of this work, directions will here be given only for building those smaller bridges, which are required on all roads. The following are specifications of some of the bridges built on the Holyhead Road.

Specification for a Bridge to be built over the main Drain in Maldraeth Marsh.

"The dimensions of the bridge as well as the shape and dispositions of the various parts are described in the annexed drawings.

"The masonry of all the abutments is to be of good hammer-dressed limestone ashler from the quarry of Nant, laid in regular courses well-jointed and bonded, without pinnings in the face.

"The newels at the extremities of the wing-walls are also to be built of good hammer-dressed ashler.

"The arch stones and string course are be of good sound freestone, which may be procured below Maldraeth Bridge and be boated up.

"The parapet coping to be of stones set on edge twelve inches in depth, each stone reaching quite over the parapet but not projecting. The sharp angles at the top are to be rounded off.

"All the rest of the masonry to be of good sound rubble masonry, built with stones from the Nant quarry, or others equally good.

"The whole of the masonry, except the inverted arches and water wings, is to be set in mortar composed of one part of good well-burned lime, and two parts of clean sharp sand, to be well-mixed and incorporated together.

"The inverted arches are to be of sound limestone, set on edge without mortar.

"The timber for the platform to be either of oak, elm, beech, or fir.

"The approaches are to be embanked at one in thirty from the ordinary level of the road; they shall have a turf mound on each side. The breadth to be thirty-two feet in the clear. The embankments to be carried up in courses not exceeding three feet each in height, and the side slopes to be two to one.

"The metalling over the roadway to be as described in the general specification.

"There are to be water wings built both above and below the large arch of the bridge of dry limestone, each twenty-five feet in length, built vertical at the abutments, and gradually increasing in batter till they are one to one at the extremities. They are to be founded six feet below the springing of the arch, and to be built up to the level of the springing. They are to be three feet thick at bottom and two feet at top.

"The inverted arches are to extend twenty feet above and below the bridge."

Specification for the Bridge at Pont-y-padoc.
Fifty feet span.

"A new bridge is to be built over the river agreeably to the drawings which are hereunto annexed. (Plate IV. fig. 1.) The masonry of the abutments is to be of good hammer-dressed stones laid in regular courses well bedded and jointed, and without pinnings in the face. The wing-walls, spandrells, and parapets, all (but the coping) are to be of good rubble masonry, composed of stones that are sound and will stand the weather, also without pinnings. The arch stones, the string course above the arch, and the parapet coping, are all to be of stone from the quarry above Rhydllanfain, or of equally good quality.

"The stones for the parapet coping are to be laid flat, well-jointed, not less than three feet in length and nine inches in thickness. All the masonry above described to be laid in good lime and stone mortar.

"There are to be water wings above and below the bridge to connect the abutments with the solid rock; they are to be built as high as the springing of the arch, and the total length

of the four walls is not to exceed eighty feet. These walls to be built of good lime mortar.

"The filling in between the wing walls, spandrells, and for the approaches, to be brought up in regular layers, or courses not exceeding five feet in height each.

"There must be dry breast walls on each side of the road at each end of the bridge, and parapets in lime-mortar on the top of each for the whole length of the 139 yards, excepting the space the bridge occupies. The line of the top of the parapet at the N. W. end of the bridge shall be an uniform incline from the point whence the lot commences to the wing walls of the bridge. The whole length to be metalled as per general specification."

Specification of a Bridge built over the Ellesmere Canal, on the Holyhead Road.

"The dimensions of the bridge are described in the annexed drawings.

"This bridge is to be built of good sound free stone or lime stone; but the two sorts are not to be mixed, and all to be set in mortar composed of one third of well slaked lime, and two thirds of clean sharp sand, well wrought together.

"The abutments, wing walls, spandrells, water

wings, and parapets, all (but the coping) are to be of good coursed rubble work; the beds and joints fairly and squarely wrought with the hammer or pick, so as not to require pinnings on the face.

"The copings of the water wings and parapets, arch, string course, and caps of newels, to be neatly drafted round the bed, and end joints, and the rest of the face to be neatly dressed with a pick point. The bed and end joints to be truly wrought.

"The coping of the wing walls to be continued through the abutment, so as to prevent the boats striking the face of the wall.

"The wing walls are to have a curved batter on the face of one and a half inches to the foot. They are to be vertical behind, with two six-inch onsets, the lowest two feet above the springing of the arch, and the upper one six inches above the crown of the arch, so that the inner line of the foundation will be one foot nearer the centre of the bridge than the inside of the parapet.

"The water wing walls are each to be forty feet long from the face of the arch. To be two feet thick at top, and three feet at bottom, each to splay back so as to cut into the land at top bank level, and to have a gradually increasing batter on their faces, so as to be not less than four inches to a foot at their extremities."

Specification for the Bridge, built on the Coventry New Road, Plate IV. fig. 2.

"The ground where the bridge is to be erected is to be excavated ten feet deep for the purpose of laying a foundation of timber for the abutments and wing walls.

"In the space thus opened, 102 piles are to be driven; they are to be six feet long: sixty-six of them, which are to be under the abutments, are to be nine and six inches; the remaining thirty-six, which are under the wing walls, are to be six inches square; they are to have a shoeing of three eighths of an inch iron, nine inches long, and two inches broad. The upper end of the piles are to be cut into a tenon to be inserted in the sills.

"The sills are to be twelve inches by nine inches, to be laid perfectly level, and their upper surface eight feet four inches below the ground line; the spaces round the pile heads and between the sills are to be firmly packed with rubble stone and grouted. A four-inch sheeting of good elm or battens is to be laid over the sills, to be thirty-three feet long, seven and a half feet broad for the abutments, and five and a half by eight and a half for each wing wall; it is to be laid close, evenly bedded and spiked to the sills. The

upper surface is to be eight feet below the ground line. On this platform the abutments are to be built of stone masonry in level beds and grouted; they are to be seven feet thick at the foundation and diminishing by two offsets, of six inches each, to six feet at the springing, which is to be at eight feet above the top of the platform; they are to be faced, nine inches thick, with blue metal bricks laid header and stretcher in clean joints. The wing walls are also to be of stone masonry, to be six feet thick at the platform next the abutments, and diminishing to five feet three inches, at eight feet from the abutments; this thickness is to be continued to the height of five feet three inches, where their length is increased eight feet nine inches; at this height there is to be an offset of one foot, and the work brought up from this to the ground line four feet three inches thick.

"The arch is to be thirty feet span, rising ten feet; to be built of the best blue brick that can be procured; it is to be one foot ten inches and a half thick at the springing, and to continue of the same thickness, from nine feet from the springing, where there is to be an offset of four inches and a half; from thence to the crown it is to be eighteen inches thick; the headers of the arch to show only eighteen inches all round. The

arch is to be turned on a centre, constructed of good timber, to be approved of by the engineer.

"The backing of the arch is to be of good stone masonry three feet six inches at the springing; at the height of two feet above the top of the abutment, there is to be an offset of one foot; at the height of four feet, there is another of a foot; and at the height of five feet to slope to the back of the arch. The water wing walls are to be ten feet long; they are to be founded at the depth of eight feet below the ground line, and to be built of stone masonry two feet thick at the bottom, and diminishing by an offset of six inches, at the height of three feet, and to continue of that thickness to the top; they are to rise to the ground line, and to be coped with sod; the splay to be three feet in each, or to be thirty-six feet in the clear at the extremities.

"The spandrell and wing walls above the ground line are to be of blue brick masonry, to be three feet thick, with nine-inch counterforts, founded on the stone masonry before described; at the height of five feet, there is to be an offset of three inches, and the remaining thickness of two feet nine inches to be continued to the road-line at this height. There is to be a string course of white freestone, six inches thick, one foot on the bed and projecting two inches over the face

of the work; the under edge to be one foot six inches above the upper line of the arch at the crown; a parapet wall is to be built on each wing wall, and over the arch of fourteen inches blue brick work, three feet six inches in height, and coped with stone three feet in length, six inches thick in the centre, and four inches and a half at the sides, which are to be flush with the brick work.

"The stones are to be well bedded and jointed with four-inched cast iron dowels, and the joints run with cement. The whole of the works and materials are to be approved of by the engineer. The mortar to be made use of is to be composed of three parts of sand to one of the best Newbold lime, to be properly worked and used while fresh. All the face work to be laid in mortar composed of two parts of Newbold lime to one of sharp clean sand."

RETAINING WALLS.

Where the natural surface of a country is very rugged and precipitous, it will frequently be necessary to build retaining walls.*

* The wall which supports the road is called a breast wall; that which is on the hill side of a road is called a retaining wall.

The following is a specification for building a retaining wall on part of the Holyhead road, in North Wales (Plate IV. fig. 3.)

On sloping ground there must be a retaining wall along the upper side of the road eighteen inches wide at top; its foundation to be laid at least four inches below the bottom of the side drains, and is to be carried up, so as to intersect the slope of the bank, when falling at the rate of two horizontal to one perpendicular, and the slope is to be formed in this manner for at least one yard from the back of the wall, by means of swarded turf or stone pavement. The face is to have a curved batter, at the rate of one inch and a half in every foot from the top: the back may be in the shape of a rough dyke wall; but every one of the back stones are to be regularly connected with the body of the wall, and not to depend upon the earth behind them."

If a retaining wall be built of brick, the thickness at top should be one brick, or nine inches, and it should increase in breadth by onsets of half a brick at every eight courses to the level of the road, below which the thickness for the stepping of the foundation should increase half a brick at every four courses to the bottom. All

walls of this description should batter in a curve line on the face at the rate of one inch in every foot.

BREAST WALLS.

These walls are necessary for supporting earth or other materials when used for forming a road; they should be built in the same way as retaining walls, and should increase, from one foot six inches in breadth at top, at the same rate as has been described for retaining walls.

These walls should have a strong coping of large stones, set on edge in mortar of the best description.

The following is a specification of a breast wall built across a very deep hollow, along an old road in North Wales on the Holyhead road (Plate IV. fig. 4.): —

" Across the hollow there is to be a breast wall built, in good lime and sand mortar, along the foot of the lower slope of the present road, or thirty feet distant from the retaining wall. This breast wall is to be two feet and a half thick at top, and to increase in thickness downwards at the rate of two inches and a half for every foot of depth, by a regular batter on the

outside. There is to be a four-feet parapet wall on the top, two feet thick at the bottom, and eighteen inches at the top."

FENCE WALLS.

These walls may be built without mortar, if the stones are flat bedded.

As their stability depends upon the workmanship, great care should be taken to have the stones properly selected, and laid in a correct and regular manner.

A coping should be made on the top of these walls; it should be of large stones set on edge, and laid in good mortar.

When walls are used for fences on embankments, they should always be built with mortar, or otherwise the shaking of the road will, in most cases loosen and throw them down.

The following is a specification for stone fences on the Holyhead road:—

"The stone dykes are to be four feet six inches high above the side drain. They are to be, when placed on breast walls, two feet thick at the bottom, and sixteen inches at the top. And where there is no breast wall below them they are to be two feet six inches thick at the foundation, and one foot six inches at the top."

CROSS DRAINS.

Cross drains should be built of good masonry eighteen inches in the clear. (Plate IV. fig. 5.)

They should be continued under the fences into the ditches on each side of the road. When made of stone masonry the side walls should be sixteen inches thick, faced on both sides, eighteen inches high at the upper end, and twenty-three inches at the lower end. The top of the walls to be level, and the bottom of the drain to have an inclination of one inch in every ten feet. The stones at top on which the covers are to be laid are to project about two inches and a half into the open space on each side, leaving about thirteen inches clear between them; the covers to be stone not less than four inches thick and twenty-seven inches long; they should be neatly jointed and closely laid together, and properly bonded on the side walls; a concave pavement of stones, not less than five inches deep, should be laid between the side walls. The body of the building should be placed so low as to admit of six inches of earth to be laid between the cover of the drain and the bottom course of the road materials, without elevating the surface of the road.

The ends of the cross drain must be secured with a strong pavement, four feet three inches by two feet three inches; the paving-stones below the discharging end should be of large stones, sunk so deep as to secure the whole from being injured by the current of water.

When a cross drain is connected with a water-course, the upper end should be secured with wing walls, at least five feet in length, and there should be the same walls at the lower end. These wing walls should be covered with two rows of swarded turf, the lower one with the swarded side down, and the upper one with the swarded side up.

The following is a specification of a cross drain, five feet diameter, built on the Holyhead road:—

"The arch to be hammer-dressed coursed work, and the rest of good sound rubble-work. It is to be in length the full breadth of the road and dikes. The faces to range with the faces of the breast walls, and the dikes to be continued over them. The breast walls, for ten feet from the face of each abutment, are to be built with mortar, and to finish by a pilaster projecting four inches, to be three feet wide at the level of the roadway, and increase in breadth downwards, by a batter of three fourths of an

inch, to a foot on each side. The dikes are also to be built in mortar between these pilasters.

"Water wings are to be built into and extended from each abutment for eight feet in length, and to splay back to eight feet apart at their extremities. They are to be founded at the same depth as the abutments, and be carried up to the level of natural ground. A stone pitching to be set between the abutments and water wings; to be set endwise to the streams, and be firmly secured at each extremity. Except the stone pitching, the whole is to be built in good lime and sand mortar. The thickness of the water-wing walls to be the same as specified for the breast walls."

Specification for a Three-feet Stone Drain.

"The arch to be hammer-dressed, and the rest of the masonry good sound rubble-work. The abutments must be continued as water wings above and below the arch, for five feet in length, and be splayed back at their extremities. To be founded as low as the abutments, and rise to the springing of the arch. A dry stone pitching to extend under the arch and between the water wings.

"Except the pitching, the whole to be set

in good lime and sand mortar up to the level of the roadway. To be the full length of the breadth of the road and dikes. The faces to range with the faces of the breast walls, and the stone dikes to be continued across the arch in the usual manner."

INLETS.

The water from the side channels of a road should be introduced into the cross drains by side openings or inlets; these should be built with stone masonry, and be ten inches by sixteen inches, and covered with sound flags, at least twenty-six inches long and sixteen inches broad, and two inches and a half in thickness. The top of these covers should be six inches above the level of the sides of the channels, and the whole of the inlet should be built outside of the side channels, as shown in Plate IV. fig. 6.

Inlets may be made along the channels, and covered with iron grates eighteen inches or two feet square; the bars of the grates should be three quarters of an inch broad, two inches deep, and one inch apart, if made of cast iron; if the grates are made of wrought iron, it is usual to set the bars in an oak curb; but the cast-

metal grates are found to answer better, particularly if bedded in stone or on brick curbing. In some situations it is found necessary to leave an opening or inlet under the footpath, as first described, as well as the grate, to allow the water to get off in thunder-storms: a provision is also sometimes made, in the casting, to allow the grates to be turned up on a hinge, in case of sudden and large runs of water.

OUTLETS.

Outlets are necessary to receive and carry off the water from the side channels of the road. These outlets may be built of brick or stone: in most cases they may be about one foot square; when they are for the purpose of carrying the water from the channels into the side drains, on grounds nearly level, they may be made of large six-inch diameter tiles or iron pipes. There should be an outlet at the end of every cutting, to allow the water that collects in the side drains through the cutting to run off to the side drains before it reaches the embankment. For want of this precaution, embankments frequently suffer very much.

DEPÔTS.

Depôts should be made on the sides of all roads for holding materials for repairing them.

The best form is that which will serve to measure the quantity of materials, as well as to hold them.

The back walls should be twelve yards long, and the two side walls each two yards and a half at the bottom, and to slope at half a right angle to the top: the height of the back and sides should be three feet. A depôt of this form and dimensions will hold twenty-five cubic yards of materials; and four of these depôts on a mile, at 428 yards apart, will contain 100 cubic yards.

The depôts should not in any case be placed farther from each other than a quarter of a mile, so as to admit the materials to be moved in barrows. This method of laying them on is better calculated for constant repairs, than drawing them with carts and horses.

Specification for building Depôts of Stone Masonry.

"Four depôts are to be built, on each mile of road, in such places as may be pointed out by the engineer or his assistant: they are to be

built with stone and lime; twelve yards long in the clear, three feet high above the side channels of the road, and to be founded as low as necessary below that, to give stability to the work; the ends to be two yards and a half in the clear at the bottom, and to rise to one yard and a half at top; the thickness of the work to be eighteen inches throughout, for the height of three feet; the work under that to be two feet thick. The top of the back, sides, and slopes to be coped with large stones, set on edge, and laid in good mortar.

"The bottom is to be flagged with sandstone, in the rough, neatly jointed and evenly bedded.

"The back and ends of the depôts to have a mound of earth thrown up against them, eighteen inches high on the outside, and eighteen inches or two feet on the base, rounded off on the top; and faced with sod if necessary, and the regular quantity of quicksets planted in it, which are to be protected by the field row of posts, and rails before described: a tile drain to be laid in front of the depôt; it is to be thirteen yards long and ten inches in the square." (See Plate IV. fig. 7.)

Specification for building Depôts with Bricks.

"Four depôts for holding repairing materials are to be erected, in each mile of road, in such places as may be pointed out by the inspector: they are to be built of brick, twelve yards long in the clear, three feet high above the side channels of the road, the foundations to be deep enough to give stability to the work; the ends to be two yards and a half clear at the bottom, and to rise one yard and a half at top; the thickness of the back and ends to be nine inches. The upper course of bricks are to be laid on edge in cement; the ends are to be secured by an oak post driven three feet in the ground, and rising one foot above the surface; the bottom is to be paved with brick on edge, and an oak plank is to be set in front, the whole length of the depôt, and flush with the upper surface of the pavement; it is to be three inches thick, and six inches deep, secured at the ends by the oak posts before mentioned, and strengthened in the middle by a post driven two feet into the ground, and of a scantling not less than four inches by six inches.

"The back and ends of the depôts are to have a mound of earth raised behind them eighteen inches deep and two feet wide, and faced with green sod; in this mound the quicks are to

be set, which are to be protected with one row of posts and rails, as above described, set on the field side. A drain is to be made in front, of brick or tiles, so as not to interrupt the passage of the water in the inner side drain."

TOLL-HOUSES.

Toll-houses should be built in a strong and substantial manner, and made suitable and comfortable for the persons who are to inhabit them. Many instances might be mentioned in which the tolls on a road have been much increased by building good houses. The following are the specifications for building toll-houses on the Holyhead road.

Specification for building a Toll-house at Llanfair, in the Island of Anglesea. (Plate IV. fig. 8.)

"The toll-house is to be built at the precise spot now marked out on the ground, and to be in shape and dimensions agreeable to the above drawings.

"The masonry to be of good sound rubble work, except the plinth, steps, and sills, which are to be of good hammer-dressed freestone, or slate. The whole to be set in good lime and sand mortar.

"The sills of the door and window frames to be of oak; the rest of the frames, and outer woodwork, to be of Baltic fir, except the posts of the portico, which are to be of sound round oak. All inside timber-work, to be of Baltic fir.

"The scantlings of timber and description of workmanship to be similar to those of the toll-house at Llandegai.

"The roof to be covered with slates, and the hips, ridges, and gutters to be covered with lead eighteen inches wide, and not less than seven pounds to the square foot.

"The inside wall and ceilings to be plastered three coats, and set. The under side of the portico, and the projection of roof, to be also ceiled and plastered, and faced with a three and a half inch fascia board. The outside to be roughcast, and coloured.

"The portico to be paved with pebble, with a hammer-dressed plinth, for the posts to stand upon, at least twelve inches wide. The octagonal lower room and the wash-house to be paved with tiles.

"All woodwork to be painted three times in oil. The inside works finished white, with doors and skirting oak colour, and the outside work dark green.

"There are to be proper grates, with slate chimney-pieces, to all the rooms.

"A garden is to be fenced round on three sides, each of twenty yards, with a walk of the same description as those on each side of the new road.

"In this garden a privy is to be built, with proper roof, dome, seat, &c. complete. There are to be two wrought-iron toll-gates hung; one across the road to Plas-newydd, and the other across that to Holyhead. There are also to be two turnstiles; the posts and rails to be of sound oak; to be painted three times in oil, white. The contractor to find all the materials and the labour."

Specification for building a Toll-house at Shelton, in the Parish of St. Chad, in the County of Salop.

"The toll-house to be built on the spot marked out by the engineer, and agreeably to the drawings.

"The whole of the walls, except the plinth, steps, and window sills, are to be of good sound brickwork, to be laid solid in good mortar, composed of lime and sand; and the outer joints to be neatly struck with the trowel. The plinth,

steps, and window sills to be of neatly tooled freestone.

"The rooms numbered 1. and 2. on the plan are to be floored with paving tile, well bedded in mortar. Those numbered 3. and 4. are to have joists of batten fir, sixteen inches from centre to centre, seven inches deep, and two inches and a half thick, and to be covered with wrought inch board of fir, or poplar. All the ceilings to have joists not less than three inches by two inches, and the roof to have rafters of the same dimensions, with purloins four inches square, under the whole of them. The ceiling, joists, and rafters to be sixteen inches from centre to centre. Hips and ridges to be one inch and a half by eight inches, and raised to receive the lead. The wall plates to be four inches and a half by two inches and a half.

"The roof to be covered with good slate, nailed on two-inch sawn lath, and to be rough-rendered inside. All the hips and ridges to be covered with lead, fifteen inches wide, and not less than five pounds to the foot, and valleys not less than six pounds to the foot.

"All ceilings to be plastered on heart lath, two coats, floated and set.

"Walls to have two coats rendered and set. The under side of the portico and projection of

the roof to be also ceiled and plastered, and faced with a three inch and a half fascia board.

"All ceilings and plastered walls to be white-washed, to have six-inch skirting round all the rooms, of fir, one inch thick.

"Outer door frames to be of oak four inches square. The front door to be two inches thick, six-panelled, square, and rusticated. The back door to be of one inch and a half deal, ledged, ploughed, tongued, and beaded.

"Inner door frames to be of fir, not less than four inches by three inches. Inner doors of one and a half inch fir, six panelled. Window frames to have oak sills, and the rest of the framing to be of fir, glazed with best second diamond fashion in lead, with quartered oak casements and iron saddle bars.

"There is to be a five eighth of an inch beaded angle staff at every external angle of the plastering.

"All timber work, except where otherwise expressed, to be of Baltic fir.

"The porch to be supported with oak or larch poles. All the timber work usually painted to be painted three times in oil. The inner doors and skirtings to be finished chocolate colour; the rest of the interior to be white; all the outside to be painted dark green.

"Grates must be fixed in the fireplaces, each

of which must have stone hearths, jambs, and mantels.

"All doors and windows to have proper locks, hangings, and fastenings; and the whole house to be finished in a complete and workmanlike manner.

"A privy must be built near the house, with proper seats, roof, door, &c. complete, to be placed in such situations as may be pointed out by the commissioners' engineer or his assistant."

Specification of a Toll-house, built near Coventry, on the New Road. (Plate V. fig. 1.)

"The precise situation to be marked out by the chief engineer of the parliamentary commissioners, or the resident engineer: it is to be constructed agreeably to the annexed plan and following particulars:—

"The excavation of ground for the walls to be of sufficient depth to obtain a solid foundation; the whole of the walls to be formed at the same depth, and the earth to be firmly pinned up to them after they are built."

Brickwork.

"The exterior walls are to be two bricks in thickness at the foundation, and be continued at

that thickness up to six inches above the outside ground line, where there must be an offset, on the inside, of two inches and a quarter; at six inches above the floor line, or twelve above the outside ground line, there must be another offset on the outside, so as to bring all the walls to be a brick and a half in thickness, which thickness is to be continued to the roof. At the height of nine feet above the floor line, and ten above the outside ground line, all the brickwork to be of sound stocks laid in well-wrought mortar, composed of one part of good lime, and two of clean sharp sand; the two middle rooms to be laid with good paving bricks; the chimney-shaft above the roof to be half a brick in thickness, finished with proper coping; all the flues to be pargetted smooth.

Carpenters' Work.

"For the roof, which is to rise a quarter of the span, all the rafters are to be four inches deep, two inches in thickness, and laid at the distance of sixteen inches from centre to centre; the hip, ridge, and gutter pieces to be six inches deep, and one inch and a half thick; the ceiling joists to be the same, laid at the same distance, and framed to the rafters.

"The two bedrooms to have flooring-joists of

the same dimensions and distance as the rafters; and laid with inch deals, folding wrought, and nailed. The front and back door sills are to be of oak, nine inches by six inches, and three inches in the walls. Window sills to be of oak nine inches by three inches, with a weathering of one inch.

"The front and back door frames to be of oak, four inches square, framed, rebated, and beaded.

"Interior door-frames to be of fir, four inches by three inches, framed, rebated, and beaded. All window frames to be of fir, three inches square, with two mullions in each, three by two inches, rebated and moulded, for lead lights; all the rooms to have six-inch ovolo skirting, one inch thick, with proper grounds; all angles inside to have a three-quarter inch bead, with quirks wrought in plastering."

Slaters' Work.

"The roof to have sawn laths, two inches by half an inch; and to be covered with the best countess slates, laid in a proper manner, and fixed with clout nails. A two-inch beaded fascia to be run along the ends of the rafters, which is to be bracketed underneath. The projection to be fifteen inches, the slating

to be pointed in the inside with plaster mortar; the wall top to be beam-filled."

Joiners' Work.

"The front door to be six-panelled, bead, flush, and square, two inches thick; the back door to be four-panelled, square, and rusticated, one inch and a half thick. The interior doors four pannelled, square, one inch and a half thick; all the wood work (except where specified to be of oak) to be of sound Baltic fir. All framed and outside work to be of yellow fir, as well as flooring boards."

Plasterers' Work.

"All the walls inside to be rendered, floated, and set, also the outside of the blank windows. All ceilings to have two coats on sound heart laths, and be properly set. All the plastering to be afterwards white washed two coats."

Plumbers', Painters', and Glaziers' Work.

"All hips, ridges, and gutters of the roof to be covered with lead fifteen inches in breadth, and not less than 7 lbs. to the superficial foot. All door frames, window frames, skirtings, angle beads, fascia, and all wood and iron work whatever, to be painted three coats in oil; the doors and

skirtings to be finished an oak colour. The windows to have small diamond glass, in lead and iron casements."

Ironmongery.

"There are to be iron frames for lead lights for all the windows; the middle to be an opening casement, with proper hinges and fastenings. The front and back doors to be hung with four inch best buts, and each to have a strong rim lock, and two bright bolts; all the inner doors to be hung with three inches and a half buts, and each to have a strong rim lock.

"Plain square grates to be fixed in each of the fire places."

Miscellaneous Matters.

"All the fireplaces to have neat, plain, square stone jambs, lintels, and mantels.

"A toll board to be made and painted with the rates of tolls, and fixed up where directed by the engineer.

"The contractor to find all materials and labour, and finish the whole to the satisfaction of the before-mentioned engineer, on or before the day of ."

TOLL-GATES AND BARS.

A toll-gate should never be placed on a hill or at the bottom of one. When carriages are going up hill, the horses must make a great exertion to put a carriage into motion after being stopped at a toll-gate. Many fatal accidents have occurred from having toll-gates just at the bottom of hills.

When circumstances render it unavoidable that a toll-gate should be placed at the bottom of a hill, the gateway should be very wide. If a single gate be used, it should not be less than fifteen feet in the clear: but, in such a situation, it is much better to make double gates, meeting in the middle, without a centre post; by these means an opening may easily be had of from twenty-four to thirty feet in the clear.

Toll-gates should be painted white, to make them more easily seen in the night-time. They are frequently made too high. When this is the case, they are more expensive and unsightly than low gates, and their additional weight acts as a powerful leverage in straining and pulling the hanging post out of its place.

The toll-gates erected by the parliamentary

commissioners at South Mims, and on the Coventry road, are only four feet six inches high: they open to sixteen feet in the clear (Plate V. fig. 2.); the posts on which they are hung are made of the best oak; they are sunk five feet in the ground, and are secured by brickwork and struts; there are also two bars passing diagonally from post to post, by which means they are firmly braced together.

These gates are hung on Collinge's patent hinges, which are particularly fit for this purpose; they run about five feet along the upper and under rail of the gate, and are connected by a diagonal piece of metal, carried from the bed of the lower hinge to the point of the upper one, in order to prevent the gate from sinking. The balls of the hinges are cast with the caps and plinths of the posts, so that the posts are not weakened by holes or mortices, as in the usual manner of hanging gates. The caps and plinths of metal are also a great security to the posts, by preserving them from the effects of the weather, and by preventing the wheels of carriages from chafing their angles.

Flapping posts are set in the ground at proper places to prevent the gates from opening too far, and straining the hinges; these posts are about two feet and a half above the ground, and two

feet in it. Catches or clicks are let into these posts, to hold the gates open when thrown back; these catches project about two inches from the side of the posts, and turn on a pin within the post, the inner end of the catch being made heavier than the outer, and always throws that end up, and by that means it takes hold of the bottom of the lower bar of the gate, by a notch cut in it for that purpose: by making the catches in this way, they are out of the reach of injury. In the common way they are put on the top of the posts, from which they project six or seven inches; in consequence of which they are frequently torn off by wheels of carriages and waggons.

LAMPS.

All toll-gates should be well lighted; and for this purpose nothing is better than a lamp made similar to the best coach lamp, with powerful reflectors, and large air holes. The gates at Coventry, and most of those in North Wales, are lighted by lamps of this description, which are found to be economical, and to answer every purpose. These lamps are about nine inches high, and six inches wide in the clear; they cost about 1*l.* 7*s.* each.

MILESTONES.

Milestones are convenient and agreeable to travellers, and also useful in enabling coachmen to keep their time with accuracy. They are also serviceable in assisting road surveyors in laying out and measuring work. They should be made of very hard stone of a light colour; and they should be much larger than they usually are, in order that they may be readily seen, and have space enough for having on them large figures; for unless the figures are large it is difficult to read them, when going very fast. A drawing of a proper-shaped milestone, as used on the Holyhead Road in North Wales, is given in Plate V. Fig. 4.

CHAP. VIII.

MANAGEMENT OF ROAD WORKS.

When a new road is to be made, as soon as the precise line of it is finally determined upon, the following circumstances should be particularly attended to.

I. Drawings to show, 1st, the natural surface of the ground; 2nd, the longitudinal inclinations of the proposed road; 3d, the slopes of the cuttings and embankments; 4th, the form of the bed of the road, and footpath; and 5th, the courses of materials to be laid on, and the thickness of each course.

Drawings should also be made, describing the plans of the bridges, culverts, cross drains, inlets, outlets, depôts, and fences which are required to be made.

II. A specification should be prepared, to explain in detail the precise method of executing every part of the work.

III. After the specification has been settled, an estimate should be made of the expense to be incurred.

The following is the estimate for making part of the Holyhead Road, near Coventry: —

FIRST DIVISION: *Seven Stars to Coventry.*	£	s.	d.	£	s.	d.
To removing 26790 cubic yards of earth, at 9*d.* - -	1004	12	6			
To 1882 lineal yards road-making, at 15*s.* 6*d.** - -	1458	11	0			
To 1882 lineal yards of fencing, at 5*s.* - - -	470	2	0			
To drains - - -	50	0	0			
To forming - - -	100	0	0			
To sodding - - -	100	0	0			
To depôts - - - -	48	0	0			
To bridge - - -	670	0	0			
To side roads - - -	20	0	0			
To gates - - -	8	0	0			
To 5200 cubic yards extra embankment, at 6*d.* - -	130	0	0			
To extra carrriage of Hartshill stone - - - -	81	0	0			
				4140	5	6
SECOND DIVISION: *Coventry to Allesley.*						
To removing 38990 yards of earth, at 9*d.* - - -	1462	2	6			
To 3760 lineal yards road-making, at 15*s.* - - -	2820	0	0			
To 3760 lineal yards of fencing, at 5*s.* - - -	940	0	0			
To drains - - -	95	0	0			
To forming - - -	100	0	0			
To sodding - - -	156	0	0			
To gates - - - -	16	5	0			
To side roads - - -	19	0	0			
To Allesley bridge - - -	82	3	6			
To skew culvert - -	150	0	0			
To depôts - - -	96	0	0			
				5936	11	0
				10076	16	6

	Miles	Yards
Length of First Division -	1	122
Length of Second Division -	2	240
Total Length	3	362

* The stones used for this road were brought eight miles from the quarries at Hartshill near Nuneaton.

IV. The next step to be taken, is to make a contract for executing the work.

Contract work is commonly supposed to be preferable to other work, for no other reason than because it is the cheapest, but experience shows that, when it is properly regulated, it is by far the best mode of securing sound and durable work. This, however, will not be the case if the contracts and specifications are prepared by unskilful and inexperienced persons, if inspection is omitted, and if the contractors are driven by excess of competition to make bad bargains.

But if the plans, specifications, and estimates for making a road are properly prepared, then the most safe and satisfactory way of having the work properly executed will be by letting it to a contractor.

As there is no difficulty in making an accurate estimate of the sum which a new road ought to cost, if a contractor of established reputation for skill and integrity, and possessing sufficient capital, is willing to undertake the work for the estimated sum, it will always be decidedly better to make an agreement with him than to advertise for tenders.

If a contractor cannot be got, possessing the qualifications which he ought to have to justify a private arrangement, then an advertisement

must be had recourse to. But when tenders are delivered in, it is very important to take care to act upon right principles in making a selection from them. The preference should invariably be decided on by taking into consideration the skill, integrity, and capital of the persons who make the tenders, as well as the prices which they offer; for if a contractor be selected without skill, or integrity, or capital, merely because his tender is for the smallest sum, the consequence will inevitably be imperfect work, every kind of trouble and disappointment, and frequently expensive litigation.

The true principle to go upon in selecting a contractor is to lean in favour of liberal terms; and rather to overpay than underpay him. He should be made quite confident by his bargain, that he will receive a fair profit for his time and labour; he will then embark in his work with spirit, and be led by a desire to gain reputation to perform his agreement to the satisfaction of all parties; but when, in following an opposite principle, a contractor is led by competition to undertake a work for a price that is too low, he starts, from the commencement, by having recourse to every species of contrivance for avoiding the fair fulfilment of what he is required to perform; every thing is done in an imperfect

way; sub-contracts are made at inadequate prices, a continual contest is carried on between the contractor and the inspector, and most commonly the whole concludes in a law-suit, the ruin of the contractor and his securities, and great loss to tradesmen and others by debts due by the contractor and his workmen.

V. After fixing upon a contractor, a deed of contract is to be prepared. In this the contractor should be bound to execute the work not only according to the general conditions contained in the deed, but also according to drawings and specifications to be annexed to it.

The deed should contain a clause to provide that no deviation should be made from it or the specifications, except by agreement in writing; and also a clause to provide for settling all disputes by arbitration. The other clauses which are fit to be inserted in the deed will hereafter be described, by inserting an exact copy of a deed, according to which a part of the Holyhead Road was made.

VI. Before the work is commenced, an inspector should be appointed to lay out the work, to settle the levels, and to see that every particular thing required to be done, is done precisely according to the specifications.

A person to be qualified to act as an inspector

of a contract should have considerable experience as a civil engineer; he should be strictly sober and honest, and of reserved habits; he should avoid familiarity with those he is placed over; his disposition should be somewhat inclined to be severe, but he should be actuated at all times by the highest principles of justice and honesty in his conduct.

A chief engineer who is engaged in conducting public works will owe his success in great measure to the skill and care with which he selects the inspectors of his contracts. The necessity of making such selections forms an essential part of his occupation, and requires considerable talents to direct it.

Above all things, a chief engineer should possess the quality of securing implicit obedience from those under him, by showing a decided superiority in the knowledge of his profession, and by acting with unsparing severity whenever the occasion may require it.

VII. It is of importance to arrange the mode of paying a contractor with punctuality; by doing so he may be kept under more control, and he will be able to perform his engagements in a more complete manner. For this purpose the deed of contract should provide that the work, as it proceeds, should be measured by the

inspector every fourth week, and that a certificate should be given by him to the contractor for the value of the work that he finds executed according to the terms of the contract, deducting, in each certificate, one tenth part of the sum, to be withheld till the whole work be finished. This plan affords the best description of security for the faithful performance of a contract.

If, in place of acting upon a regular plan of paying a contractor, he is kept out of his money, he will often be placed in difficulties, and rendered incapable, however willing, to perform the conditions of his contract in a perfect manner.

As nothing can contribute more to explain the proper manner of making a road than the deeds and drawings according to which good roads have been made, an exact copy will be now inserted of the deed of contract, according to which upwards of three miles of road were made by the Parliamentary Commissioners of the Holyhead Road near Coventry. As this deed was prepared by an eminent barrister, it may be safely made use of, as a precedent, by road trustees, engineers, and solicitors. There will be found, in the specifications annexed to the deed, a good deal that has been already brought forward; but this repetition will serve to impress the more

firmly those principles which should always be followed.

DEED OF CONTRACT FOR THE COVENTRY IMPROVEMENT.

Articles of agreement made and entered into the fourteenth day of November, in the year of our Lord one thousand eight hundred and twenty-seven, between Thomas Baylis, of Stratford-upon-Avon, in the county of Warwick, Road-maker, of the first part; John Kershaw, of the parish of Sapworth, in the said county of Warwick, Esquire, of the second part; and Alexander Milne, of Whitehall, in the county of Middlesex, Esquire, on behalf of the Commissioners acting in execution of an Act of Parliament passed in the eighth year of the reign of His present Majesty King George the Fourth, intituled, "An Act for the further improvement of the Road from London to Holyhead, and of the Road from London to Liverpool," to whom the said Alexander Milne is Secretary, of the third part. Whereas the said Commissioners having caused it to be made public that they would receive proposals for making, forming, and completing two new pieces of road, one commencing at or near the Seven Stars public-house at Whitby, in

the county of the city of Coventry, at the spot distinguished on the map or plan here annexed by the letter A, and extending from thence to the present road opposite Lygon's mills, where it terminates at the spot marked on the said map or plan by the letter B; and the other new piece of road commencing in Spon Street, near St. John's Church, in the said city of Coventry, at the spot distinguished on the said map or plan by the letter C, and extending from thence to the village of Allesley in the said county of Warwick, where it terminates at the spot marked on the said map or plan by the letter D; and the several drains, walls, culverts, bridges, fences, embankments, field-gates, and works connected with the said new road, according to the specifications and general observations comprised and set forth in the first schedule hereunder written, and the plans and sections hereunto annexed, he the said Thomas Baylis delivered in the proposal contained in the second schedule hereunder written for executing the said roads, drains, walls, culverts, bridges, fences, embankments, field-gates, and works in manner aforesaid, and at the prices or sums mentioned in the same proposal; and the said proposal having been duly accepted by the said Commissioners, he the said Thomas Baylis hath agreed to enter into the covenants

hereinafter contained for the due performance thereof respectively; and the said John Kershaw hath, at his request, agreed to become his surety in manner and to the extent hereinafter mentioned; and the said Alexander Milne, on the part of said Commissioners, hath agreed to enter into such stipulations as are hereinafter mentioned with respect to the payment, in manner and at the time hereinafter mentioned, of the consideration money to be paid to the said Thomas Baylis. Now therefore these presents witness, that in pursuance of the said proposal hereinbefore referred to, and in consideration of the sum of ten thousand and seventy-six pounds sixteen shillings and sixpence (the sum mentioned in the said proposal), to be paid as hereinafter mentioned, he the said Thomas Baylis doth hereby for himself, his heirs, executors and administrators, in manner following (that is to say), that he the said Thomas Baylis, his executors or administrators, shall and will forthwith undertake, and with diligence proceed in the execution of, and duly complete or cause to be completed on or before the 25th day of March which will be in the year of our Lord one thousand eight hundred and twenty-eight, the said first mentioned piece of road between the Seven Stars public-house and Little Park Street aforesaid, and shall

and will forthwith undertake, and with diligence proceed in the execution of, and duly complete or cause to be completed on or before the twenty-fifth day of March which will be in the year of our Lord one thousand eight hundred and twenty-nine, the said secondly hereinbefore mentioned piece of road between Spon Street and the village of Allesley aforesaid, together with all and singular the drains, walls, culverts, bridges, fences, embankments, field-gates, and other the works in the said first schedule mentioned, according to the specifications and general observations contained in the same schedule, and the plans and sections hereto annexed, and at the price or sum mentioned in the said proposal contained in the said second schedule; and further, that the said Thomas Baylis shall and will, in all respects, faithfully, readily, and diligently abide by, observe, perform, and keep the said several terms and stipulations mentioned in the said specifications and general observations, and pursue the said plans and sections, according to the true intent and meaning thereof, and shall not nor will make any deviation therefrom, without the license, consent, and approbation of the engineer for the time being of the said Commissioners, in writing, for that purpose first had and obtained; and that the said Thomas

Baylis, or some experienced and responsible person on his part shall, from time to time, pay due personal attendance to the said several works, as the same shall be carrying on, and shall at proper times be ready to be conferred with, by the Inspector appointed by the said Commissioners; and these presents further witness, that in pursuance of the said agreement on this behalf, and in consideration of the premises, he the said Alexander Milne doth hereby for himself, his executors and administrators, covenant, promise, and agree with and to the said Thomas Baylis, his executors, administrators, and assigns, in manner following (that is to say), that in case he the said Thomas Baylis shall and do well and truly perform and keep the several stipulations and agreements herein contained, referred on the part of him the said Thomas Baylis, his executors or administrators, to be performed and kept according to the true intent and meaning of these presents, then they the said Commissioners for the time being, or such person or persons as shall from time to time be appointed by them for that purpose, shall and will well and truly pay or cause to be paid unto the said Thomas Baylis, his executors, administrators or assigns, the said sum of ten thousand and seventy-six pounds ten shillings, in manner hereinafter men-

tioned (that is to say), at the end of each twenty-eight days from the time when the making of the said Roads or Works shall be begun upon as aforesaid, and shall pay or cause to be paid to the said Thomas Baylis, his administrators, executors or assigns, nine tenth parts of the sum which shall be payable in respect of or be taken as the consideration for the work that shall have been done in the course of the twenty-eight days immediately preceding; and, further, that for the purpose of ascertaining how much of the said sum of ten thousand and seventy-six pounds ten shillings shall be taken for the consideration for each twenty-eight days' work, the engineer for the time being of said Commissioners, or his assistants shall, at the end of each twenty-eight days, measure the work done, or otherwise estimate the same, and shall report or state how much of the said sum of ten thousand and seventy-six pounds ten shillings ought to be taken as the consideration for the work done during the twenty-eight days immediately preceding each such admeasurement or other estimate, and that the nine tenth parts of such stated or reported price or consideration shall, immediately after each such admeasurement or other estimate, be paid to the said Thomas Baylis, his executors, administrators or assigns as aforesaid: and, fur-

ther, that within one month after the whole of the said roads, drains, walls, culverts, bridges, fences, embankments, field-gates, and works shall be completed, according to the true intent and meaning of these presents, all the residues which shall then remain unpaid of the said sum of ten thousand and seventy-six pounds ten shillings shall be paid to the said Thomas Baylis, his executors, administrators or assigns; and the said John Kershaw, in pursuance of the said agreement in this behalf, doth hereby bind himself, his heirs, executors, and administrators, unto the said Alexander Milne, his excutors, administrators and assigns, in the sum of twenty thousand pounds, to be paid to the said Alexander Milne, his executors, administrators or assigns, by the said John Kershaw, his heirs, executors or administrators*: Provided, and it is hereby agreed and declared, that if he the said Thomas Baylis, his executors and administrators, shall duly observe, perform, and keep the covenants and agreements herein contained on his and their parts, then the above written obligation on the part of the said John Kershaw shall be void, or otherwise shall remain in full

* In subsequent contracts less security was required; the stopping of the one tenth of each month's payment being found the best security.

force; and it is hereby further covenanted, concluded, and agreed, that in case any addition, alteration, or deviation shall be made at the desire of the said engineer, in writing, to, in, or from the plans or particulars, or either of them, every such addition, alteration, or deviation shall be paid for separately, and shall be subject to the like agreement with respect to materials and workmanship, as hereinbefore contained with respect to the making and completion of the roads and works, according to the aforesaid plans and particulars, and as if such additions, alterations and deviations had formed part of and been specified in such plans or particulars; and that no such addition, alteration, or deviation shall be considered as vitiating this present agreement, or shall in any wise affect the same, except so far as is mentioned in the stipulation last hereinbefore contained; and if such alterations shall increase or lessen the works hereinbefore stipulated to be performed, the same shall be paid for or deducted as the case may be, at rates corresponding with the value of similar works hereinbefore contracted for: Provided, and it is hereby further covenanted, concluded, and agreed upon, by and between the said parties to these presents, that in case any doubt, dispute, or question shall arise, touching and

by virtue of this agreement, or touching or concerning the true intent and meaning of these presents, all such doubts, disputes, or questions shall be referred to the decision of two referees; one to be named and appointed by the said Alexander Milne on behalf of the said commissioners, and the other to be named and appointed by and on the behalf of the said Thomas Baylis; and in case such two persons shall not agree in the premises, and make their decision and determination in regard thereto in writing, under their hands, in one month after the same shall be referred to them, then, and in such case, all such doubts, disputes, or questions shall be referred to such third person as the two persons so to be chosen aforesaid shall for that purpose nominate, and whose decision and determination thereon shall be binding and conclusive between the said parties, so as the same may be made in writing within one calendar month from the time the same shall be so referred to him as aforesaid. In witness whereof the said parties to these presents have hereunto set their hands and seals, the day and year first above written.

and all irregularities of the surface of the ground to be cut down or embanked upon, as no extra claim will be admitted.

The breadth of the finished road is to be 35 feet; 30 feet for the carriage-way, and 5 feet for the footpath. (Plate VII. fig. 1.)

The slopes of all embankments from the outsides of the finished road are to be two horizontal to one perpendicular, neatly dressed, and covered with green sod, at least four inches thick, evenly laid and closely jointed. (Plate VII. fig. 2.)

The slopes of the cuttings on the southern side to be three horizontal to one perpendicular, those of the northern side to be two horizontal to one perpendicular; these slopes are also to be covered with sod, the green side placed uppermost, evenly laid and properly jointed; it may be procured on the space to be occupied by the road and its side slopes. (Plate VII. fig. 3.)

The surface of the foundation for the materials of the carriage road is to be formed level from side to side. The surface of the foundation for the hard materials of the footpath is also to be level, and to be six inches above that of the carriage road. In the cuttings, the breadth between the bottoms of the side slopes is to be thirty-three feet. (Plate VII. fig. 1.)

Upon the level space prepared for the road materials, a bottom course, or layer of stone, is to be set by hand in form of a close firm pavement. (Plate III. fig. 3.)

The stones set in the middle of the road to be seven inches in depth; at nine feet from the centre five inches; at twelve feet four inches; and at fifteen feet three inches; and to have a curving surface; they are to be laid on their broadest edges lengthwise across the road, and the breadth of the upper edge is not to exceed four inches in any case. All the inequalities of the upper part of said pavement to be broken off with a hammer, and all the interstices to be filled with stone chips firmly wedged or packed, so as to form a convexity of four inches in the breadth of fifteen feet from the centre. The stones used for this purpose are to be such as will not waste by exposure to the weather.

The bed of pavement or set stone is to be covered with a layer of Nuneaton stone, to be approved of by the inspector; it is to be laid six inches thick on the middle of the road, eighteen feet wide. These stones are to be broken into pieces as nearly cubical as possible; the longest and largest piece to go through a circular ring of two inches and a half in the inside diameter.

The stones must be broken off the road, and riddled on a sieve of one inch square meshes, and approved of by the engineer or his assistant before they are put on the road. The shoulders or sides of the road are to be covered with the small stones which pass through the aforesaid meshes, properly cleansed and selected, or with good sharp coarse gravel, well cleaned and separated from all earth, and having no pebbles larger than one inch and a half in diameter, to be approved of by the engineer or his assistant. This course of gravel is to be seven inches and a half thick at nine feet from the centre; six inches and a half at twelve feet from the centre; and two inches and a half at the sides, or fifteen feet from the centre.*

The Nuneaton stone is to be covered with one inch and a half in depth of good binding gravel, to be laid on at such times and in such way as may be directed; and the whole surface, from side to side, to be kept properly dressed and levelled, until the whole work is certified to be completely finished.

* Since this specification was drawn up, it has been considered better to increase the depth of pitching at the sides, so as to give a convexity to the road surface of six inches instead of nine.

The footpath is to be coated with six inches of sandstone, broken to the same size as stated for the road materials, and is to be covered with gravel, so that the surface of the footpath shall be on a level with the middle of the road.

DRAINAGE.

Along the outside of the carriage road (all embankments excepted), drains are to be cut, ten inches wide at bottom, fourteen inches at top, and ten inches deep below the surface of the bed for the road materials. (Plate VII. fig. 4.) Mitre drains are to be made from the middle of the road into these drains, forming such angles at the middle as may give a declivity for conveying the water into the side drains; they are to be nine inches wide at bottom, twelve inches at top, and ten inches deep; there are to be thirty of these drains per mile (embankments excepted). These drains are to be filled with rubble stone, connecting with the bottom course of road materials. An edging of turf, with the green side out, not less than six inches in depth, and five inches in thickness, is to be set in a neat compact manner on the road edge of the footpath, and the top thereof is to be covered with the binding gravel.

On the outside of the footpath, along the border for the thorns, a turf six inches high and four inches thick is to be set in the same way over the whole line, excepting on embankments.

There are to be eight cross drains of dry stone masonry, each eighteen inches in the clear, constructed in every mile of the road. These cross drains are to be continued under the fences into the ditches on each side of the road. The side walls to be sixteen inches thick, faced on both sides, eighteen inches high on the upper end, and twenty-three at the lower. The top of the walls to be level across the road, and the bottom to have an inclination of one inch in every ten feet. The stones at top, on which the covers are to be laid, are to project about two inches and a half into the open space on each side, leaving about thirteen inches clear between them. The covers to be sound stone, not less than four inches thick and twenty-seven inches long. They are to be neatly jointed, closely laid together, and properly bonded on the side walls, and covered with four inches of turf. A concave pavement, with stones not less than five inches deep, to be laid between the side walls, as shown in the drawings (Plate IV. fig. 5.). The whole of the building to be placed so low as to admit six inches of mould to be

laid between the covers and the bottom course of stone, without raising the longitudinal surface of the road. When the cross drains are under an embankment, the same are to be carried to the extremities of the bottoms of the slopes. Should any drains of a different size be wanted, their situation, number, size, and value to be determined by the inspector. The water from the surface of the road to be introduced into the cross drains by as many side openings or inlets as there are cross drains ten by sixteen inches, built on each side, and covered with stones at least twenty-six inches long, fourteen inches broad, and not less than two inches and a half thick. The bottom of said covers to be five inches above the side drain, and the whole of each opening to be on the outside of the driving way. The ends of the cross drains to be secured by strong pavements, four feet three inches by two feet three inches. The water collected in the side drains of the road to be introduced into the cross drains by a row of paving stones across the course, so raised as to prevent it from passing the opening of the cross drain; and the outer row of paving stones below the discharging end to be large stones, sunk so deep as to secure the whole from being injured by the current

of water. The lower ends of the drains to be secured by wing walls, at least five feet in length, and the same at the upper end, where they are connected with a watercourse, and to be covered with two rows of swarded turf; the lower one with the swarded side down, the other with the swarded side up. Wherever springs are found in the surface of the ground on which the road is to be made, or in the cuttings, drains to be made the same as on the outside of the carriage road, before described, for carrying the water into the ditches or natural watercourses, by proper under-draining. Open cuts to be made whenever they are necessary for carrying off the water from the ditches into the natural watercourses; and these drains to be two feet wide at the top, ten inches wide at the bottom, and eighteen inches deep. Through all the cuttings on the footpath side of the road, a drain one foot square is to be made along the lower edge of the slope, and filled with rubble stone. This drain is to be made between the footpath and the bottom of the slope, the bottom of it to be eighteen inches below the upper surface of the finished footpath; and at the opposite side of the road, the bottom of it is to be one foot below the under surface of the metal pavement, as shown in fig. 4. An open

catch drain is to be made through the cuttings, above the quicksets, and also at the tops of the slopes, where the ground inclines to the road, to be one foot deep, sloping three to one on the field side, and one to one on the road side, meeting in an angle at the bottom, and the whole neatly dressed and covered with green sod.

FENCING.

The fencing to be constructed as shown in the section, a ditch to be cut, and a mound to be raised, together occupying eight feet; the ditch to be on the field side, the mound to be cut out of the natural ground, four feet wide at top, ten inches wide at bottom, and two feet and a half deep.* The mound, of four feet wide, is to be raised by a sod, with the green or swarded side out, to the height of fourteen inches above the side channels of the road, and the top to be rounded from the ditch to the top of the sod. Two rows of quicksets to be planted on the ditch side of the mound, as shown in the section. Nine plants to be set in each lineal yard; they are to have good roots, to be two years transplanted, to be put in between the first day of November and the last day of March. A trench, eighteen inches wide and fifteen inches deep, is to be

* In wet land the drain should be at least four feet deep.

cut, and filled with good vegetable mould, in the middle of which the two rows of quicksets are to be planted; in all the cuttings, the quicksets are to be planted at the distance of eighteen inches from the footpath on the one side, and the carriage road on the other side. (Plate VII. fig. 4.) On all embankments they are to be planted so that the distance between the middle of the rows on each side shall be thirty-eight feet. (Plate VII. fig. 5.) Particular attention is to be paid to the preparation and quality of the earth of the quickbed, and every thing connected with the planting of the quicksets.

The quicksets are to be protected by two rows of posts and rails on each side of the road, three rails in each length; the posts are to be five feet long, and at least five by three inches of good oak; the rails to be not more than eight feet long, and three inches and a half by two inches and a half, and may be of good elm, ash, or fir timber. In each length of rail a prick-post is to be driven into the ground: they are to be placed in the middle between the posts, to be at least twelve inches in the ground, and well fitted, and strongly nailed to each rail. (Plate VII. fig. 6.) A mound, two feet wide and fourteen inches high, to be made below the railing

placed on the top of the embankments. Each field must be fenced off with the posts and rails before any part of the road-work is commenced in that field, or before any of the hedges or ditches now existing on the lands be removed or touched. Ten field-gates, with iron hinges and fastenings, and ground posts, all similar to the best kinds used in the neighbourhood, to be furnished and erected; and should a greater or less number be required, they are to be allowed or deducted from the contract at so much per gate. At each gate, drains with good draining tiles not less than ten inches, or of brick one foot wide, to be laid in the sides of the road; and drains of the same construction as the cross ones, one foot square in the clear, to be made in the field or outside ditches: the length of these drains to be twelve feet; and a road to be made over them into the fields, eight feet in breadth, and covered with broken stone of the same quality as used for pitching the road, to be eight inches deep, and extending into the fields ten feet at least beyond the line of the quicksets. No inclination from the road into the fields to be more than one in sixteen, and all the gates to open into the fields.

DEPÔTS FOR HOLDING REPAIR MATERIALS.

Eight depôts to be erected in each mile of road, in such places as may be pointed out by the engineer or his assistant. (Plate IV. fig. 7.) They are to be built of stone and lime, twelve yards long, three feet high above the side channel of the road, and to be founded as low as necessary below that, to give stability to the work. The ends to be two yards and a half in the clear at the bottom, and to rise one yard and a half at top. The thickness of the work to be eighteen inches throughout for the height of three feet; the work under that to be two feet thick. The top of the back, side, and slopes to be coped with large stones set on edge, and even, and flagged with sandstone in the rough, neatly jointed and well bedded.

The back and ends of the depôts are to have a mound of earth thrown up against them, eighteen inches high on the outside, and eighteen inches or two feet on the base, rounded off on the top, and faced with sod if necessary, and the regular quantity of quicksets planted in it, which are to be protected by the field row of posts and rails described before; a tile drain to be laid in

front of the open, thirteen yards long, and ten inches wide.*

GENERAL OBSERVATIONS.

All the lines to be marked out by the chief engineer to the parliamentary commissioners, or his assistant, and the general formation of the road is to be to his satisfaction; he is also to be satisfied with the solidity of all embankments, before the foundation or bottom course of pavement is laid on them. The stone used for the pavement, and the packing and setting of the same, are in all cases to be approved of by him before any broken metal is laid on. He is also to be satisfied that the top metal is of proper quality and dimensions before the binding is laid on, and that the cross drains are properly constructed and firmly backed before earth or turf is placed on them. A passage is to be constructed from the embankment at the mill near the bridge, to admit carts to Barnewall's mill and premises: it is to be fourteen feet wide, to have an inclination not more than one in sixteen, to be covered with broken stone ten inches thick at

* A specification in the original schedule for building a bridge, has been transferred to Chapter VII. on Road Masonry. The specifications also in that chapter for depôts and inlets were taken from this schedule.

the middle, and six inches at the sides; a dry stone wall to be built on the outside to retain the earth; to have a batter of two inches in three feet, and to rise three feet above the surface of the finished road, as a protecting parapet; to be fifteen inches thick at top, and increasing in thickness by an offset of three inches on the inside for every foot to the foundation; the top course to be set in good lime and mortar. A paved channel one foot and a half wide is to be laid along both sides of the road, from top to bottom; where the road crosses Folly Lane there will be a cutting of two feet. The lane must be lowered at each side of the road, and properly levelled to an inclination of one in sixteen for the whole width of the road. The part thus broken up must be coated with six inches of broken sandstone of the best quality in the neighbourhood. Tile drains are to be laid along the side of the road for the whole width of the lane at the point of intersection.

Where the road crosses the footpath at the upper angle of the weavers' row of houses on the Allesley land, a cutting is to be made of two feet six inches; the footpath must be covered on each side, and dressed with gravel, so as to give a good and commodious passage to and from the road. Where the road crosses the Chapel Lane

there is to be four feet of filling; the lane must be embanked on each side to the height of the road, and have inclinations each way of one in sixteen, the side slopes are to be two horizontal to one perpendicular, and the top surface when finished to be twenty-one feet wide; both these side roads or lanes are to be fenced in the same manner as the main line of road, and to be coated with eight inches of broken sandstone for the width of eighteen feet, and with gravel for the width of eighteen inches on each side, to be eight inches deep where it joins the broken stone and six inches at the sides.

Where the road crosses the lane between Mr. Booth's and Mr. Carter's land, a filling is to be made of two feet nine inches. The same must be embanked up to the road on each side; to have inclinations each way of one in sixteen, and to be twenty-one feet wide on the surface, with slopes of two horizontal to one perpendicular; to be covered with five inches thick of pebbles, eighteen feet wide, and gravelled eighteen inches at each side; the gravel to be three inches thick next the broken stone, and six at the sides; no fencing will be necessary on these side roads.

The second Schedule referred to in and by the foregoing agreement.

Sir,

I hereby engage to execute the works of the proposed improvement of the Holyhead Road at Coventry, according to the plan, section, and specification, for the sum of ten thousand and seventy-six pounds sixteen shillings and six-pence.

I am, Sir,
Your obedient servant,
THOMAS BAYLIS.

	£	s.	d.
First Lot . . .	4140	0	0
Second Lot . . .	5936	16	6
Total . .	10,076	16	6

To Alexander Milne, Esq.
1. Whitehall, London.

Signed, sealed, and delivered by the above-named Thomas Baylis in the presence of
John Macneill. THOMAS BAYLIS.

Signed, sealed, and delivered by the
above-named John Kershaw in
the presence of
John Macneill. JOHN KERSHAW.

Signed, sealed, and delivered by the
above-named Alexander Milne
in the presence of
John Macneill. ALEXANDER MILNE.

CHAP. IX.

IMPROVING OLD ROADS.

Mr. Telford gives the following account of the state of the turnpike roads, in 1819, in his evidence before the committee of the House of Commons on the highways of the kingdom:— "With regard to the roads of England and Wales, they are in general very defective, both as to their direction and inclinations; they are frequently carried over hills, which might be avoided by passing along the adjacent valleys; the shape, or cross sections and drainage of the roads are quite as defective as the general directions and inclinations; there has been no attention paid to constructing good and solid foundations; the materials, whether consisting of gravel or stones, have seldom been sufficiently selected and arranged; and they lie so promiscuously upon the roads, as to render it inconvenient to travel upon them, and to promote their speedy destruction. The shape of the road or cross section of the surface is frequently hollow in the middle; the sides encumbered with great banks of road dirt, which have accumulated in

some places to the height of six, seven, and eight feet; these prevent the water from falling into the side drains, and also throw a considerable shade upon the road, and are great and unpardonable nuisances. The materials, instead of being cleaned of the mud and soil with which they are mixed in their native state, are laid promiscuously on the road: this in the first place creates an unnecessary expense of carriage of soil to the road, and afterwards nearly as much in removing it, besides inconvenience and obstruction to travelling."

The committee of 1819 attributing, by their report, the imperfect state of the roads to the negligent and culpable conduct of the trustees who had the management of them, roused the attention of the public to the subject, and thus led to the introduction of an improved system of management. But although a considerable change for the better has taken place since 1819, many of the defects described by Mr. Telford still remain; and all that has been done towards removing them falls far short of what ought to to have been done to put the turnpike roads into complete order.

In improving old roads, nearly the same objects should be attended to as are to be secured in making new ones; such, for instance, as the

direction, the longitudinal inclinations, the breadth, form, and hardness of the surface, the drainage, and the fencing.

For the purpose of ascertaining in what respect an old road is complete or defective in these points, the following queries have been prepared. The answers that can be given to them will at once show what is the state of a road.

1st. Is the direction of the road in the shortest line that can be found without having to pass over steep hills or other obstacles?

2d. What are the rates of inclination on the hills? Is there no more ascent in the road than is necessary for reaching the heights of the country which must be crossed?

3d. What is the breadth of the road? Is it every where the same? Is it defined by side channels, having along them curb stones or borders of grass sods?

4th. Are the channels on each side of the road on the same level? Is the convexity of the surface uniformly the same in every part along the whole length of the road?

5th. Is there a footpath? What is the height of it above the side of the road? What is its breadth? Of what materials is it composed?

6th. Is there any waste land between the road

and the fences of the road? In what state is it?

7th. Is the surface of the road higher than that of the adjacent fields?

8th. Of what materials does the crust of the road consist? What is the depth of them in the centre of the road, and at a distance of five feet on each side of the centre?

9th. Are there sufficient drains for carrying off all rain and other water?

10th. Are the fences low? Are they raised on ground of the same level on both sides of the road? Are they of the same height on both sides, and parallel to each other?

The answers which can be given to these queries will show what the defects are of any road to which they are applied, and what is requisite to be done to improve it.

With respect to the turnpike roads as they now are, it will be found upon an inspection of them, that in regard to their direction, they are universally defective. Scarcely any road between two places is in the best line with respect to distance and hills. The reason of this is, that the present lines of roads are the same, except those of roads made of late years, as they were, when first established by the aboriginal inhabitants of the country, as footways

or horse-tracks. Let a map be made of the road from London to Edinburgh, to Carlisle, to Liverpool, or to any distant town, and this fact will be fully sustained.

The first step which should be taken towards the improvement of the principal roads of the kingdom, is the making of surveys of the mail coach roads: this work should be done by government. The engineers employed should also be required to make plans and estimates for the improvements which may appear to be necessary; and the trustees of every principal road should be furnished with copies of the surveys, and of the plan and estimates for improvements relating to the road under their care.

The number of single mail coach miles daily travelled in Great Britain, including pair horse coaches, is 15,604. The expense attending the surveying of them should not exceed 3*l.* a mile; so that the whole expense to be incurred on this important preliminary step, for the improvement of these roads, would not be of a large amount.*

Whenever the improvement to be made on an old road does not require the present line to be departed from, the road should first be put into a proper form, according to the rules already laid down, in respect to the breadth and con-

* This subject will be again referred to, in Chapter xii. on Road Legislation.

vexity of a road. A sufficiently strong crust of road materials should then be laid on; a regular footpath should be made; all the old high and crooked fences should be removed, and low ones substituted in their place, parallel to each other, at a proper distance from the road; and particular care should be taken to provide a sufficient number of drains.

Where the old road is below the level of the adjoining fields, it should be raised by embanking, so as to be, at least, two feet above them.

If it is not considered advisable to remove the old fences, and if the space between them is wider than is necessary for the roadway and footpath, the surplus portion, or waste, should be put into order; for no road can have a finished appearance unless the whole space between the fences is arranged so as to have a regular and uniform shape. This operation will also assist very much in contributing to the dryness and preservation of the road. On this point Mr. Telford makes the following observations in his Third Annual Report on the Holyhead Road:—

"I cannot too often repeat, that a surveyor should not feel satisfied that he has done his duty until the whole breadth of ground belonging to a road between the fences is put into perfect order, as this shows skill, attention, and

good workmanship. A certain space, say six feet, should be formed into a footpath of one regular breadth, with a surface made with a coating of strong gravel, or small broken stones, at least six inches deep; thirty feet should be allotted to the roadway, to be formed of one regular convexity, with the use of a properly shaped level*; one side channel should be formed by the sod margin of the footpath abutting on the side of the road, and the other by the sod margin of a flat mound of earth, of the same form as the footpath; and the whole waste between the fences should be filled or levelled, so as to have a perfectly smooth surface. The wastes should also be sown with grass-seeds; and where the soil is clay, the scrapings of the road should be carefully spread over them, till they become firm. When the fence of a road is a hedge, this should be cut and clipped every year by the surveyor, at the expense of the trustees; and the work should be done in such a manner as to leave the side and horizontal lines of the hedge perfectly straight and even.

"In order to assist the surveyors in putting their roads into a good shape, I have drawn up the following Specification:—

* See Plate VII. fig. 8.

" *Specification for the Regulation of the Surface between the Fences, so as to establish uniformity in the Cross Section.*

" 1. The road is to be 30 feet wide, with a fall of six inches from the centre to the side channels; but exclusive of footpaths.

" 2. A sod to be laid on each side of the road, 8 inches wide, and 6 inches in thickness; and in such a manner as to form a sloping edge; the top surface of the sods on each side to be exactly on the same level.

" 3. On one side of the road a footpath to be made behind the sod; it is to be 6 feet wide, and to have an inclined surface of one inch in a yard towards the road; and another sod to be laid along the outer edge of the footpath, eight inches wide, the top of it on a level with the footpath.

" 4. On the other side of the road a flat mound of earth is to be formed behind the sod, on a level with the top of it, six feet wide; the surface of this mound is to be sown with grass seeds.

" 5. The waste land on each side, where there is any, between the footpaths, or the mound, and the road fences, to be dug over to the

breadth of four feet, at right angles to the fences, and made quite smooth; when these wastes are covered with grass, the sod to be pared off each breadth, and laid on the breadth last dug; when they are not in grass, the new surface is to be sown with grass-seeds.

"6. If there is a ditch on the road side of the fence, or if the road-fence consists of a high bank, a new post and rail-fence is to be made close along the footpath or mound, with a ditch on the field side, at least three feet deep."*

If the foregoing rules were strictly attended to, the safety of fast travelling by night coaches would be very much increased. The accidents which occur by night, arise chiefly from coachmen getting off the road, and running the wheels of coaches on high footpaths or other high banks of earth immediately on the sides of the road; but if no footpath were higher than six inches above the side channel of the road, and if a flat mound were formed of the same height, on the side opposite to the footpath, coachmen, on getting off the road in fogs or snow storms, would be able to pull into it, or stop, without any danger of being overturned.

* For a description of the operations of the Parliamentary Commissioners in improving the Holyhead Road, see the Report of the Select Committee of the House of Commons in 1830, in Appendix, No. 4.

The parish roads are capable of being very much improved by attending to a few general rules. Twenty feet in breadth of the middle of the road should be carefully set out and defined by a row of sods on each side.

The surface of the road should be brought to a convexity of six inches from the centre to the sides, by laying on good road materials, and so as to have the surface of the road on its sides on a level with the top of the sods. The ruts should be filled with hard materials from time to time.

The space on each side the road between the sods and the fences should be lowered or raised, so as to make it smooth, with an inclination of one inch in a yard, from the sides of the road to the fences. Drains should be made along the fences, and all water-courses and drains connected with the road should be constantly kept open, and free from weeds.

Those parish roads which are very narrow, and the surface of which is below the level of the adjoining fields, and on which streams of water are constantly running, should be new-made, by raising them with earth, and forming a roadway of good materials on the embankment.

CHAP. X.

REPAIRING ROADS.

The business of repairing a road should always be managed on a regular and fixed plan.

The following matters require particular attention: —

1st. The quality of materials.

2d. The quantity to be put on per mile per annum.

3d. The preparation of the materials.

4th. The method of putting them on the road.

5th. The number of labourers to be employed.

1st. With respect to the quality of the materials to be used, the hardest should always be preferred; for it should ever be borne in mind, that hard stones brought from a distance are found by experience to be cheaper in the end than those of a softer kind which may be got near the road, at a much lower price.

Another reason for making use of the hardest materials that can be procured, is the greatly increased labour of horses, which is occasioned

by working into a smooth surface often renewed coatings of weak materials. With respect to the subject generally of road materials, it may be observed, that the best descriptions consist of basalt, granite, quartz, syenite, and porphyry rocks.* The whinstones found in different parts of the United Kingdom, Guernsey granite, Mountsorrel, and Hartshill stone of Leicestershire, and the pebbles of Shropshire, Staffordshire, and Warwickshire, are among the best of the stones now commonly in use. The schistus rocks being of a slaty and argillaceous structure, will make smooth roads, but they are rapidly destroyed when wet by the pressure of wheels, and occasion great expense in scraping, and constantly laying on new coatings. Limestone is defective in the same respect. It wears rapidly away when wet, and therefore, when the traffic on a road is very great, it is an expensive material. Sandstone is generally much too weak for the surface of a road, it will never make a hard one. It is very well adapted to the purpose of a pavement, as a foundation for a road. Flints vary very much in quality as a road material. The hardest of them are nearly as good as the best limestone, but the softer kinds are

* For the hardness of some kinds of stone, see Appendix, No. III.

quickly crushed by the wheels of carriages, and make heavy and dirty roads. Gravel, when it consists of pebbles of the hard sorts of stones, will make a good road, particularly when the pebbles are so large as to admit of their being broken; but when it consists of limestone, sandstone, flint, and other weak stones, it will not; for it wears so rapidly, that the crust of a road made with it, always consists of a large portion of the earthy matter to which it is reduced. This prevents the gravel from becoming consolidated, and renders a road made with it extremely defective with respect to that perfect hardness which it ought to have.

2d. With respect to the quantity of materials to be put on a road in the course of a year, this should be regulated by the traffic on the road and the durability of the materials. The object to be secured, is the giving to the road a sufficient degree of strength to have it at all times smooth and hard. The materials to be provided should be quarried, carted, and broken by contract. The materials when brought in their rough state to the road, should be packed in depôts, or laid up on the wastes, in regular shaped heaps, so as not to interfere with the side channels of the road.

3d. When the materials are stone, they should be broken, as before described for making new

roads, to a size of a cubical form, not exceeding two inches in their largest dimensions.

When gravel is used, the persons who dig it should be required to pass it through sieves before it is carted to the road, so that no gravel pebble, less than one quarter of an inch in diameter, should be carried from the pits to the road.

When the gravel is brought to the road, it should be again sifted by the road labourers, so as to separate the pebbles that are less than three quarters of an inch in diameter from the rest; and all the large pebbles exceeding one inch in diameter should be broken.

4th. The materials, after they have been properly prepared, should be laid on in small quantities at a time: care should be taken to fill up ruts or hollows as soon as any appear.

In those places where the surface of the road has become much worn, a coating of one inch and a half of materials should be laid on: that is to say, a coating only a single stone in thickness, when stones are used; and when gravel is used, a coating not exceeding one inch in thickness. If more materials are necessary, they should be laid on after the first coating is worked in.

The work of repairing roads by laying on new coatings of materials ought to be done between

the months of October and April, and when the surface of the road is wet. By laying on the materials at this season of the year in thin coatings, they are soon worked into the surface without being crushed into powder, and without producing any great distress to horses drawing carriages over them.

5th. When the funds will admit of it, a road should be divided into districts of four miles each; and a foreman, with three labourers, should be appointed for each district. The foreman and one or more of the labourers should be daily on the road, taking care that the side channels of the road are kept clean, and making good any injury to the road as soon as it appears.

The foreman should work with the men: he should take care that the orders of the surveyor are attended to, and be able to measure road work.

A regular plan should be arranged, and strictly adhered to, for keeping the water channels and drains of a road always open, and free from dirt.

In the month of October in each year, every water channel and drain should undergo a general repair, and be cleared of all deposited earth and weeds.

At the same time, the surface of the whole road should be scraped, all ruts and hollows

should be carefully filled with materials, and all weak parts of the surface coated with materials; that is to say, the road should be put in every respect into a complete state of repair, so as to preserve it from being broken up during the approaching winter.

A road should be scraped from time to time, so as never to have half an inch of mud upon it; this is particularly necessary to be attended to, when the materials are weak; for if the surface is not kept clean, so as to admit of its becoming dry in the intervals between showers of rain, it will be rapidly worn away.

The road men should scrape from the centre to the sides; the mud should not be scraped into or allowed to remain in the channels, as is too frequently the case; but put into small heaps, about one foot from the side channels, so as not to stop the running of water in them.

These heaps should always be removed, the moment the mud is sufficiently dry to admit of its being put into carts or barrows.

The scrapings should never be laid in heaps on the wastes or footpaths; they should be spread evenly over the hollow parts of the wastes, till the wastes are brought to a regular surface; afterwards they should be carted at once off the road to some convenient place

adjoining the road till they can be otherwise disposed of.

Constant attention on the part of a road surveyor is necessary to keeping hedges clipped, and the branches of trees in the fences lopped. The hedges should be cut so as to be as low as they can be kept without making the fence unfit for confining cattle within them. The superior condition of roads, at all times, crossing uninclosed land, shows how valuable a full exposure to the sun and wind is, in contributing to the preservation of roads.

The trustees of a turnpike road should require their surveyor to lay before them, at the commencement of every year, an estimate of the work he proposes to perform in the ensuing year. In this estimate every particular should be specified; namely, the quantity of materials to be provided, the prices to be paid for them, the labour to be employed, &c., &c. The surveyor should be required to make up an account at the end of every month, of the money received and paid by him; and he should also make up an annual account, showing the particulars of the year's expenditure, the quantity of materials bought and carried to the road, the sums paid for day labour, for task work, and for cartage, &c.

In some cases the practice has been introduced of employing a pay-clerk to pay for all the road expenses, in order to relieve the surveyor from all trouble about pecuniary matters, and at the same time to remove as much as possible all temptation to swerve from his duty. This practice has been attended with the best effects, and cannot be too strongly recommended.

CHAP. XI.

ROAD INSTRUMENTS AND TOOLS.

THE principal instruments employed in surveying and laying out roads are theodolites, spirit levels, and sextants.

Theodolites.

Theodolites in careful and experienced hands are the best instruments for laying out a road, and for taking horizontal angles and intersections. The rates of inclination can be determined at once by means of the vertical arch, without any measurement by the chain being required: they are decidedly the best instruments.

Theodolites are made of various sizes and prices; but those that are five inches in diameter, and cost about 17*l.* are the most suitable for road purposes.

These instruments are divided on the limb into spaces of thirty minutes, and by means of a vernier, single minutes can be read off with great precision.

They are furnished with a good telescope and

spirit level, besides two levels on the limb set at right angles to each other, and a magnetic needle or compass in the centre, which is of use in getting the magnetic bearing of any line in the survey, or of taking the bearings independent of the divisions on the limb.

The theodolite is used in the following manner in surveying a road.

When the line of direction is fixed upon, the theodolite is set up over the first point in the survey: it is then adjusted by means of the spirit levels, so as to be perfectly level. The eye piece of the telescope is moved in or out until the hairs are seen distinctly; and the object glass is adjusted to distinct vision according to the distance of the levelling staff from the instrument. Zero on the limb is then brought to coincide with zero on the vernier plate, and the limb and plate are then clamped together. After this is done, the whole head is turned round, until the north point on the compass box coincides with the north point of the needle. The limb is then screwed fast, and the vernier plate unclamped and turned round until the staff is seen through the telescope: the vernier plate is then clamped, and the observation completed by turning the tangent screws of the limb and of the vertical arch, until the centre

of the vane exactly corresponds with the centre of the cross hairs in the telescope. The degree and minute on the limb and vertical arches are then read off and entered in the field book.

The distance from the instrument to the staff is then measured by the chain, and all offsets are at the same time measured and entered in the book. The length of the distance line is then carefully entered, and the theodolite removed and again set up directly over the point previously occupied by the levelling staff: this may be done by means of the plumb line usually attached to the instrument. The next operation is to adjust the instrument perfectly level, and to send the staff back to the point originally occupied by the theodolite. The vane having been previously adjusted to the exact height of the centre of the telescope, the head of the instrument is then turned round until the staff is seen in the field of view of the telescope: the head is then clamped, and the bisection made by means of the tangent screw; the vernier plate still remaining steadily clamped to the limb. The vertical arch is then examined, to see if the degree and minute corresponds with those previously observed: if not, the first observation must be repeated. The vernier plate is then unclamped, and the telescope turned round towards the next line of direction

until the staff appears in the field of view; when this is effected, the vernier plate is clamped, and the observation completed as before. In this way the survey is carried on; and the perpendiculars and rates of inclination are afterwards calculated, and the plan and section laid down in the usual way.

Spirit Levels.

Troughton's levels, which are considered the best, are usually made with very powerful telescopes and delicate ground spirit levels. These instruments are usually fourteen inches long; but some are eighteen and others twenty inches long. They cost from 12*l.* to 18*l.*, and are so well balanced and secured, that they will not require, with proper care, for a long time, any adjustment.

The method of using these instruments is as follows:

When the direction of the road has been marked out, a line is measured by a chain commencing at the beginning of the new line, and terminating at that point where the inclination of the surface of the ground changes, or where the line of direction changes. This distance is carefully entered in the field book. The spirit level

is set up as nearly as possible in the middle of this line, and a levelling staff with a vane is held by assistants at each extremity of the line: the telescope is then adjusted for distinct vision, and its axis brought to be truly vertical by means of the spirit level and parallel plates. The telescope is then directed to the staff, which is placed at the commencement of the line, and the assistant is directed to lower or raise the vane until it is bisected by the cross hairs in the telescope; the height marked by the vane on the staff is then set down in the field book in the column headed (back observation). The telescope is then turned round until the staff at the termination of the line is perceived in the field of view; the necessary signals are then given to lower or raise the vane on the staff until its centre coincides with the cross hairs in the telescope: the height of the vane on the staff is then entered in the field book in the column marked for observation, and the magnetic bearing of the line is also observed and set down in another column. Sometimes only one staff is used, in which case it is removed from the first to the second station after the observation is made. When very great accuracy is required, the level is set up by measurement exactly in the centre between the two staffs, for by this means the errors of adjustment and any

slight deficiency in the instrument are compensated and mutually destroy each other.

Sextants.

The small pocket sextant is a most useful instrument in making road surveys; after a little practice, it can be used with great facility, and will be found a superior instrument to the common surveying needle, and much more accurate, besides affording the most expeditious method of making surveys of any yet known.

ROAD TOOLS.

Spades.

In some parts of the clay districts, a narrow spade, considerably curved in the blade, technically called a grafting tool (Plate VII. fig. 10.) is much used, particularly in cutting deep drains in stiff clay.

Shovels.

The best description of shovel for road work is pointed in the blade, and has a curved handle to allow the workmen to bring the blade flat to the ground without stooping. (See Plate VII. fig. 13.)

Trucks.

When metal rails can be laid down, the truck or small waggon is the best description of carriage for removing earth; a drawing of one of these is given in Plate VII. figs. 11 and 12. they usually hold a cubic yard of earth. The body is generally made of elm, the frame of oak, and the wheels and axles of iron.

Hammers.

Two descriptions of hammers, which are the most useful in road works, are represented in Plate VII. figs. 15 and 16. The handles should be flexible and made of straight grained ash; particularly those used for breaking pebbles: the small hammers should have a chisel face, and the larger ones a convex one, about five-eighths of an inch in diameter. Those made of cast steel are the best; and though expensive in the first cost, they wear much better than wrought iron ones, and very seldom break at the eye.

Pronged shovels are useful for filling stones, when broken, into carts or barrows; a drawing of one is given in Plate VII. fig. 7. A man is enabled to lift stones with much greater ease and more expeditiously with one of these shovels

than with a common one; besides, he lifts them without taking up any earth with them.

Scrapers.

Scrapers are sometimes made of wood shod with iron, but those made of plate iron are preferable: they should be six inches deep, and from fourteen to eighteen inches long in the blade, according to the materials of which the road is composed; the softer and more fluid the mud, the longer the scrapers should be; they turned a little round at the ends to prevent the mud from escaping. The best scrapers are made of old saw plates, stiffened on the back by a rib of wrought iron, or by riveting the plate to a board of elm, cut to the proper width and length and about half an inch thick.

Hedging Knives.

These instruments have been long used in Scotland, where they are called plashing tools: they are made of different sizes; that represented in Plate VII. fig. 14. is the most useful. When a labourer is a little practised in the use of them, he can trim a hedge as well as a gardener with a pair of shears, and much more expeditiously. They should be made sufficiently light to enable a man to use them with one

hand, and care should be taken by the maker, that they are properly balanced on the handle, otherwise a workman will not be able to wield them with proper effect; the great error in making these instruments in England, is that of making them too heavy, and curving the blade too much.

Working Levels.

Working levels are absolutely necessary in laying out new works, and in repairing old roads. These instruments are easily used by common workmen. One of the best kind of these levels is represented in Plate VII. fig. 8. in which A B C represents the level, upon the horizontal bar of which are placed four gauges, *a*, *b*, *c*, *d*, made to move perpendicularly to the line A C, in dove-tailed grooves cut in the horizontal bar. When any of these are adjusted, to project a proper depth below the line A C, it may be fixed by a thumb screw, which will retain the gauge in the desired position.

Fig. 9. shews a section of the horizontal bar drawn to a larger scale, as marked upon the edge of the gauge. This section is taken through the line *e f* of fig. 8. In this figure the position of the square iron bolt, or screw pin, is more plainly seen, and also the washer placed

under the thumb screw. Three of these bolts pass through the horizontal bar, fig. 8. exactly three inches above the line A C; the other, seen at *d*, is only two inches above the same line.

Levels lor laying out slopes are best made of a bar of wood, three inches deep, one inch thick, and six feet long; on the centre near the middle of the rod, a triangular piece of wood of the same thickness is nailed; the sides of this triangular piece are so formed, that when the rod is placed upon a slope of one to two or one to three, a small pocket level placed on one side of the triangle will be horizontal, and the bubble will remain in the centre.

Ring Gauges.

Ring gauges for ascertaining the size of the broken stones are extremely useful. A ring of this description is represented in Plate VII. fig. 17.

CHAP. XII.

ROAD LEGISLATION.

Turnpike System.

It is owing to the turnpike system of road management that England is so superior to other countries with respect to her public roads.

The legislature, by giving powers to persons willing to come forward as subscribers, commissioners, or trustees, and act together for the purpose of making new roads, or improving old ones, adopted the wisest principle for securing an abundance of good roads.

Had the legislature refused to incorporate those persons who have executed the duties of turnpike trustees, and given the management of the roads to the government, or left them wholly with the parishes, this country could never have reached the degree of wealth and prosperity to which it has arrived, for want of proper means of inland communication.

It must be quite clear to every one who has carefully examined this subject, that nothing but leaving the management of the roads to

those persons who live in their neighbourhood, would ever have induced the people of England to pay, as they now do, a road revenue, arising from turnpike tolls, to the amount of 1,200,000*l.* a year *: for, although tolls are in every respect fair and proper for maintaining a road; and although Government, by employing scientific engineers, might have expended the produce of them with greater skill than country gentlemen; the hostility to pay them, if they had been wholly at the disposal of Government, would no doubt have prevented the making of useful roads so universally over the whole country as they have been made under the established system.

It should be remembered, that turnpike roads owe their origin, in many instances, to private subscriptions of considerable amount; and, in every such case, the main inducement to subscribe must have been the entrusting of the management of the funds to the subscribers, and giving them corporate powers.

The same principle of association has led to the making of the canals, the docks, the great bridges, and all the most useful public works of the country; and it is not conceivable how

* See, in Appendix, No. VI., an Account of the Income, Debt, and Expenditure of all the Road Trusts in England.

such large funds for making new roads, or for converting parish roads into turnpike roads, could have been obtained as have been obtained, if the legislature had not acted on this principle.

But although it is unquestionably true, that it is to the turnpike system that the abundance of useful roads is owing, it must at the same time be observed, that great errors have been committed in carrying the system into operation. For however numerous and however useful the roads may be, they are, as has been already stated more than once, extremely imperfect, in comparison with what they might and ought to be.

In respect to the lines of direction, it has been observed that the roads are every where extremely faulty. They have, commonly, been carried over all the hills between the points of of communication, when they might have been kept on comparatively level ground along the valleys of the country.*

While the most magnificent improvements have been going forward in all other kinds of public works, displaying the greatest efforts of human skill, and a rapid advancement in the science of civil engineering, scarcely any road

* Foreigners who have heard of the boasted goodness of English Roads, must be surprised when they see the Dover Road. No road shows so conspicuously the low state of the art of road-making in England as this road.

can be pointed out, except a few which have been put under the management of civil engineers, that is not defective in the most essential particulars.

Who is to blame for this? Not the Government, because the business is not in its hands. The leading men of the commercial and manufacturing classes, who have been chiefly concerned in forming companies for making canals, docks, bridges, and other splendid improvements, are not to blame, for they have been too generally excluded from the business of road management. Nor are the civil engineers of Great Britain to blame, because they have seldom been consulted: on the contrary, this profession has been too commonly deemed, by turnpike trustees, as something rather to be avoided, than as useful and necessary to be called to their assistance.

The country gentlemen of England, in point of fact, are alone responsible for the defective state of the roads, because the business of managing them has been vested by the legislature exclusively in their hands.

Dr. Adam Smith bears testimony to the bad management of road trustees in his time. He says: " The money levied is more than double of what is necessary for executing, in the completest manner, the work, which is often executed

in a very slovenly manner, and sometimes not executed at all." This remark, in too many cases, is just as applicable now, as it was when first made, nearly sixty years ago.

In those instances where a turnpike road is used merely for local purposes, however defective it may be, those persons only are put to inconvenience who live near it; but, where a turnpike road forms the communication between populous cities or towns, at a considerable distance from each other, then the misconduct of trustees, whether arising from negligence, ignorance, or corruption, is of serious importance, and loudly calls for correction and control.

We shall now proceed to state what appear to be the principal errors which have been committed in our road legislation in giving effect to the turnpike system.

According to the provisions of every Turnpike Act, a great number of persons are named as trustees: the practice is to make almost every one a trustee, residing in the vicinity of a road, who is an opulent farmer or tradesman, as well as all the nobility and persons of large landed property; so that a trust seldom consists of fewer than 100 persons, even if the length of the road to be maintained by them does not exceed a few miles. The result of this practice

is, that in every set of trustees there are to be found persons who do not possess a single qualification for the office; persons who conceive they are raised by the title of a road trustee to a station of some importance; and who, too often, seek to show it, by opposing their superiors in ability and integrity, when valuable improvements are under consideration; taking care, too frequently, to turn their authority to account, by so directing the spending of the road money as may best promote the interests of themelves or their connections.

It sometimes happens that if one trustee, more intelligent and more public spirited than the rest, attempts to take a lead, and proposes a measure in every way right and proper to be adopted, his ability to give advice is questioned, his presumption condemned, his motives suspected; and as every such measure will, almost always, have the effect of defeating some private object, it is commonly met either by direct rejection, or some indirect contrivance for getting rid of it. In this way intelligent and public spirited trustees become disgusted, and cease to attend meetings; for, besides frequently experiencing opposition and defeat at the hands of the least worthy of their associates, they are annoyed by the noise, and language with which the dis-

cussions are carried on, and feel themselves placed in a situation in which they are exposed to insult and ill usage.

Numerous cases could be quoted to prove the accuracy of what is here stated; but it is unnecessary to do so, because every one acquainted with the subject, who reads these remarks, will readily allow their general correctness, and be prepared to admit that the sketch might easily have been still more highly coloured.

There is one effect of having these large bodies of managers, which is particularly deserving of notice, and that is the necessary want of uniformity and system in their measures. It often happens that, when some important business is to be performed, one set of ten or twenty trustees, after devoting a great deal of their time in attending meetings, finally decide upon some useful measure, when another set of trustees summon a meeting, and rescind all their fellow trustees have done. This is a course of proceeding which is, of itself, sufficient to establish, beyond all dispute, the absolute necessity of some considerable change in the existing system.

Notwithstanding the state of the turnpike roads was enquired into by select committees of the House of Commons in the sessions of 1819,

1820, and 1823, and in consequence of their reports a new general Turnpike Act was passed in 1823, the evil of the mal-administration of the powers of trustees has not been cured by the 153 clauses contained in this act. The evil, in point of fact, having its source in the principle on which the governing body of road business is formed, is not of a nature to be cured by a multitude of regulations; and the framers of the law committed a great error in overlooking this point. It is the principle of having such a number of trustees that throws every thing belonging to road operations into confusion, and produces the waste of the road funds. A law, therefore, to do any good, should provide that the number of trustees shall be limited within some rational bounds.

The committee of the House of Commons, appointed in 1823 to enquire into the state of the turnpike roads say, in their report,—"Your Committee would therefore strongly recommend to the House the consideration of the subject of making and managing the roads of the kingdom in the course of the ensuing session of parliament; feeling convinced, that whatever plausible appearance the plan may assume of appointing a large number of noblemen, gentlemen, farmers, and tradesmen, commissioners

of the roads, that the practice has every where been found to be at variance with the supposed efficiency of so large a number of irresponsible managers; and that the inevitable consequences of a continuance of this defective system will be to involve the different trusts deeper in debt, and leave the roads without funds to preserve them in proper order."—(*Report*, p. 9.)

But besides diminishing the number of trustees, another step should be taken in order to secure a uniform and efficient system of managing the executive business of maintaining a road.

Each body of trustees should be obliged to elect by ballot a committee of seven trustees, in whose hands every thing relating to the business of managing the road should be vested. What belongs to the management of the revenue and general affairs of the road might be transacted by the body at large. But all the funds, after paying the officers, and interest on loans, should be at the disposal of the committee. The committee should be required to lay half-yearly accounts before the body at large, with reports of their proceedings.

To enable such a committee to act with effect, they should have full power to appoint and dismiss surveyors.

This plan is not altogether new in road legislation. In Ireland, an act was passed in the year 1798 (5 Geo. III. c. 41.) for the Malahide Roads, in which there are the following provisions: — By clause eight, "the trustees of said roads shall, as soon after the passing of the act as conveniently may be, meet, and, at such meeting, elect by ballot, from among the trustees, three persons for each line of road, to be directors for managing the several lines of the said roads, for which they shall be respectively elected directors, and for transacting all business relative to the same." By the fourteenth clause, the directors are to have all powers necessary to carry the act into execution; and it is expressly provided, that the consent or direction of the said trustees shall not be necessary to authorise, nor shall restrain or prohibit the directors to do any act towards carrying the said acts into execution.

By the fifteenth clause, quarterly accounts are to be laid by the directors before the trustees.

Another great evil of the existing system, which a new law should correct, is that of placing a line of road under the management of too many separate Boards of trustees. With respect to cross-country roads, it may be difficult to apply a remedy to the evil; but as to all the

great main roads of the kingdom, a law should be passed to consolidate the existing trusts, so as to have at least fifty miles in each trust. All the mail-coach roads in each county should be placed under the management of one trust.*

* Extract from Mr. Telford's First Annual Report on the Holyhead Road, dated May 4th, 1824, p. 25.—"Perfect management must be guided by rules and regulations; and these must be carried into effect by the unceasing attention of a judicious and faithful surveyor, who has, by actual experience and attention, acquired a thorough knowledge of all that is required and applicable to the general and local state of particular districts, as regards soil, materials, and climate; likewise the sort of wear to which the surface is liable. A person possessed of all these requisites, and otherwise properly qualified to level and set out new lines, &c. where necessary, must receive the remuneration such a character merits, and may always obtain, in this active and industrious country. But however convinced and well disposed trustees may be to give this remuneration, the tolls of five or six miles do not afford the means of giving it. The consequence is, that the Shifnal Trust (four miles) has hitherto been under the management of a person so little acquainted with proper road business, that it becomes a serious consideration, whether it will be prudent to suffer the extensive improvement at Priors Leigh to be entrusted to his care. Until the Parliamentary Commissioners interfered, and showed a practical example, the Wellington Trust (seven miles) was managed almost wholly by the clerk: he had a sort of foreman, who appeared to be only partly employed on the road. And on the Shrewsbury Trust (seven miles), as has already been stated, the surveyor and contractor were united in the same person. All these managers proceeded without regard to any rules and regulations whatever; receiving only occasional directions

There remains to be noticed another very great defect in our legislation on roads, namely, the want of some power to control the trustees of turnpike roads, to prevent neglect and corrupt practices. No other trustees are free to do whatever they please with perfect impunity; and no reason can be given for not making every one who takes upon himself the office of a road trustee accountable before a proper tribunal for his conduct in the discharge of the duties of it. Dr. Adam Smith has remarked this great defect in the turnpike laws of not providing such a control. If a Board of trustees suffer the road under their care to get into a bad condition, the only remedy now is to indict the parish through which the road passes; but nothing can be more contrary to every principle of justice than such a state of law. In all

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from some of the most active of the trustees, whose varying opinions served more to distract than benefit the practical operations of the workmen. I must beg leave to add, that these observations are applicable to all trusts of similar extent; and are evidence of the propriety of establishing districts of a magnitude to justify a more perfect arrangement, and the employing of a properly qualified surveyor, whose sole occupation should be the road under his care, and who should also be enabled to keep constantly employed a set of workmen thoroughly conversant with road operations, and working chiefly by contract."

cases where trustees have the management of landed property applicable to the maintaining of buildings, bridges, and roads, proceedings may be taken against them in the court of King's Bench, if they abuse the trust reposed in them. In the case of roads, the circumstance of the funds for maintaining them being derived from tolls should make no difference, and they should be equally liable with the trustees of estates to be brought before this court. But this remedy would not be sufficiently easy and efficacious. A more direct and easy course of proceeding would be to allow complaints against trustees to be brought by petition before the Judges at assizes. The Judges should be empowered to try, with a jury, the allegations contained in the petitions; and in case of a verdict in favour of the petitioners, they should be enabled to set aside the trustees, and name commissioners to take charge of the road for as long a period as they might think advisable.

In order further to afford protection to the public against the misconduct of turnpike trustees, the House of Commons ought not to allow Turnpike Bills to be passed as a matter of course. A particular set of standing orders should be framed for the purpose of keeping road trustees in check. No Bill should be allowed to be read a first time in the House of Commons, for renew-

ing an act, until after a select committee had been appointed to examine minutely into the state of the road, and into the accounts of it; and time should be allowed for petitions to be presented to the House against the Bill, and for having the allegations contained in them fully examined.

But in addition to the measures now proposed, however well adapted they may be for putting the trustees of turnpike roads under more control than they now are, another should be taken further to secure an upright and efficient discharge of their duties, namely that of placing them under the immediate superintendence of a public Board of commissioners.

The Commissioners of Land Revenue are well suited to act as a Board for this purpose. They have recently been appointed to do the business heretofore done by the Board of Works, and also to execute the powers vested in the Commissioners of the Holyhead Roads.

If this plan were adopted, the commissioners should have power given to them to cause annual inspections to be made by competent civil engineers, of all the principal roads in England, Scotland, and Wales, so as to obtain accurate information concerning the proceedings of every turnpike trust. Every trust should be obliged to furnish them with an annual account of its

income, expenditure, and debt, and they should also have authority to enquire into the details of the income and expenditure of every trust. An annual report should be made by the commissioners to parliament, containing a summary of the information derived by them from their inspections and enquiries.

This Board, in addition to what is here required of it as a Board of Control, should be enabled to act as a Board to assist the trustees in making alterations and improvements. It should be authorised to have surveys made of all the mail-coach roads of Great Britain. These surveys should show the ground plan of each road, its vertical longitudinal section, and the alterations and improvements that may be made in it. The Board should furnish each trust with a copy of the survey of the road under its management, and be enabled to make an arrangement with it for carrying the necessary alterations and improvements into execution.

In order that the Board may be placed in a situation to be competent to make such an arrangement, similar powers should be given to it to issue Exchequer bills to those possessed by the Commissioners (under 57 Geo. 3. c. 54.) for issuing Exchequer bills for public works. Loans should be made to the trustees, and they should be permitted to lay on additional tolls to

pay interest at the rate of three per cent., and to provide a sinking fund for repayment of at least three per cent. more.

But the money raised by these loans should not be paid over to the trustees; it should be held by the Board, and expended by it in making the intended alterations and improvements

The Board should have power to purchase land, procure materials, and to do whatever is necessary for making new roads.

This plan is the same as that which has been acted upon by the Parliamentary Commissioners in making the improvements on that part of the Holyhead Road which lies between London and Shrewsbury.

When the Parliamentary Commissioners undertook the improvement of this road in 1820, the portion of it between London and Birmingham was one of the worst roads in England. The consequence was, that nearly all the travelling from London to Birmingham was by Oxford, though the longest road by eight miles; but now the travelling has been transferred from the Oxford line to the Coventry line; so that the plan now proposed, with respect to the prospect of its success, has the sanction of experience.

It may further be mentioned in support of it, that the trustees on the Coventry line acknow-

ledge the great advantages they have derived from the interference of the Parliamentary Commissioners, and have always acted cordially with them.*

If this plan for assisting trustees in improving the roads, were applied in the first instance only to the principal mail-coach roads, the expense to be incurred by the Board of Control in making surveys and inspections would be of moderate amount. These might be made by resident civil engineers, acting under a chief engineer. The salary of each resident engineer need not exceed 300*l.* a year. Four assistant engineers in England, and one in Scotland, would be able to do all the business necessary for making surveys and reports, until the Board of Control should have to execute new works. The resident civil engineer, under Mr. Telford, who conducted for several years all the works on the road between London and Shrewsbury, received but 200*l.* a year. He made a survey of the whole line; prepared all the plans, estimates, specifications, and drawings for the

* Mr. Huskisson, as Chairman of the Commissioners of Land Revenue, was, *ex officio*, Chairman of the Commissioners of the Holyhead Road. When the author proposed to him the plan of placing the trustees of this road under their control, he fully approved of it, saying that, if the plan succeeded, all the roads of the kingdom ought to be placed under a similar control.

improvements; inspected the contractors; and instructed the surveyors of the local trusts in carrying on the repairs of the road.

The following extract from the report of the Committee of the House of Commons in 1819, on the public highways, contains remarks which concur fully in principle with the recommendations now given for the improvement of the turnpike roads.

"The importance of land-carriage to the prosperity of a country need not be dwelt upon. Next to the general influence of the seasons, upon which the regular supply of our wants, and a great proportion of our comforts, so much depend, there is, perhaps, no circumstance more interesting to men in a civilised state, than the perfection of the means of interior communication. It is a matter, therefore, to be wondered at, that so great a source of national improvement has hitherto been so much neglected. Instead of the roads of the kingdom being made a great national concern, a number of local trusts are created, under the authority of which large sums of money are collected from the public, and expended without adequate responsibility or control. Hence arises a number of abuses, for which no remedy is provided; and the resources of

the country, instead of being devoted to useful purposes, are too often improvidently wasted.

"Your Committee do not mean, by these observations, to recommend that the turnpike roads of the kingdom should be taken into the hands of Government, as such a measure is liable to various objections; more especially as it would be difficult to compel either the Government or its agents to keep the roads in a proper state of repair; and as, in process of time, the roads might be considered rather as a source of revenue, than an accommodation to the public. But your Committee are perfectly convinced, that leaving matters in their present state is in the highest degree impolitic. They are of opinion, that a Parliamentary Commission ought to be appointed, to whom every trust should be obliged annually to transmit a statement of its accounts, to be audited and checked. Before these commissioners any complaints of improper expenditure, by which so many innocent creditors suffer, ought to be brought and enquired properly into. An annual report of the state of the turnpike roads of the kingdom ought also to be laid, by such commissioners, before his Majesty and both Houses of Parliament. Such a commission would not be attended with any expense to the public treasury, as a small poundage on the

money received by the different trusts would defray all the expenses it could possibly occasion.

"Nor is this all the advantage that would be derived from the proposed establishment. Under the direction of such an Institution, the necessary experiments might be tried, for ascertaining the best mode of forming roads, and the best means of keeping them in repair; the proper construction of carriages and wheels; and the system of legislative provisions, the best calculated for the preservation and improvement of roads. All these are points which cannot be brought to the state of perfection of which they are capable, without some attention on the part of the legislature; nor by committees of the House, occasionally appointed, however zealous in the cause. Such great objects, which would add millions to the national income, and would increase the comfort of every individual in the kingdom, can only be successfully carried through by a great and permanent Institution, whose whole attention shall be directed to that particular object; and who would take a just pride in accomplishing some of the greatest benefits that could be conferred on their country."*

* Since these pages were sent to press, a Committee of the House of Lords have made a report on the state of the Turnpike Roads, which contains the following paragraph: —

The expense which must unavoidably be incurred in making roads as roads ought to be made, is in many cases so great, that it is not possible to acquire sufficient funds by any rate of toll which would be submitted to; and therefore it becomes necessary to provide some plan for obtaining them by other means. When the improvement required is of a principal mail-coach road, the public is so much interested in it, that the counties should be enabled to levy a rate, to be given in aid of the road tolls.* The mail coaches also should pay tolls, not to the trustees, but to the Board of Control, to be applied by it in making improvements. It

"All the witnesses who have been examined to that point concur in recommending a system of general control over the management of the roads of the kingdom, with a view to prevent an increase of debt, to introduce one general, economical, and skilful course of management, as the only means of reducing the present great amount of debt, and of relieving the country from the burden of statute labour and the high rate of toll now levied in many districts. The Committee are of opinion that such control would be attended with the most beneficial results, and recommend that measures should be taken to carry the same into effect."

* By the 45 Geo. 3. c. 43. power was given to the Treasury to advance to the grand juries of Ireland, loans for making and improving mail-coach roads, to be repaid in instalments by county rates. Several excellent roads were made in this way, according to surveys furnished by the Post-office, and all the loans have been repaid.

might also be proper to apply a part of the revenue to this purpose, derived from the duties on post-horses and stage coaches.

All past legislation on roads may be said to have failed in producing perfect roads, in consequence of most erroneous notions about the cost of making a good road. The want of correct opinions with respect to what constitutes a good road has commonly led to overlooking the necessity of providing adequate funds. With the greatest economy and skill, it is seldom possible to make a long line of new road in a proper manner, with no other funds than the money raised on the credit of the tolls of it.

PARISH ROADS.

The roads, commonly called parish roads, in England, are generally in a very imperfect condition. This is owing chiefly to the law by which the management of these roads is placed under the governing authority of the vestries of the parishes through which they pass. Blackstone says, "In England every parish is bound, of common right, to keep the roads that go through it in good and sufficient repair, unless, by tenure of lands or otherwise, the care is conveyed to some particular persons."

The principle here established, of placing the common roads of the kingdom (not being turnpike roads) under as many separate governing authorities as there are parishes, is, in every respect, repugnant to any thing like a sound principle of management; and, until it be abandoned, no efforts of legislation can prove successful in introducing any real improvement.

So long as this radical error in principle shall be recognised by parliament, it will be labour in vain to pass acts of parliament containing a multitude of new regulations. The influence of the original cause of the evils which prevail will render them, as they have rendered hundreds of similar regulations, wholly abortive.

Legislation on the highways of England, to be of any practical good, must be founded on a more enlarged view of the subject; and instead of the governing authority of a parish, it seems advisable that that of a county should be substituted; or, when counties are very large, that of a division of a county.

The reasons which may be given to support this general proposition are so obvious, that it is unnecessary to state them all in detail; two only will be noticed. The first is, that the private interests of a vestry lead it to be satisfied with very imperfect roads. A road that

will allow a waggon to be drawn upon it without much difficulty, will answer the purpose of those who compose the vestry. But such a road need not have any other qualities, than two ruts for the waggon wheels, and a track-way for the horses. The second reason is, that the limited extent and funds of a parish will not admit of giving such a salary to a surveyor as will secure the services of a person educated in the principles of road management, and otherwise qualified for the office of surveyor.

The next great error in principle, as to legislation on the common highways, is the means by which the funds for maintaining them are provided, namely, statute labour; and it may be said with respect to this point, as it has been already said with respect to the former, that so long as this radical error in principle shall be recognised by parliament, it will be labour in vain to pass new acts to remedy existing evils.

A third great error in the system of parish management consists in the regulation by which a surveyor is appointed to act only for one year. This practice is founded on the vulgar notion, that the management of roads is something that requires no education; that it is not an art which requires skill and science. This practice may be set down as one which had its origin in

very rude times, and which long usage has made familiar; but it certainly is one which ought to be abolished in the present enlightened state of society.

To legislate, therefore, on sound principles, the old custom of seeking to mend what is wrong, by laws containing a multitude of new regulations, must be abandoned: the country gentlemen who, as members of parliament, undertake the task of legislating on the subject, must look more to general principles; and, to succeed, they should no longer act upon the principle of making parish vestries the governing authority; the principle of acquiring funds for the maintaining of the highways from statute labour; and the principle of appointing annual surveyors.

The course which ought to be followed for introducing a more perfect system of management in England will be mentioned in the description now about to be given of the management of roads in the Scotch counties, under modern acts of parliament.

SCOTCH ROADS.

The principal roads in Scotland are turnpike roads, and the acts are similar to those of England, and partake of similar defects; but in

consequence of the excellent materials which abound in all parts of Scotland, and of the greater skill and science of Scotch trustees and surveyors, they are superior to the turnpike roads of England.

The highways which are not turnpike roads, or under the modern county acts, are managed under the regulations of the old laws of Scotland.

Two general meetings of the justices of each county, and of the Commissioners of Supply, must be held yearly, to order matters concerning the highways; and the conveners of the counties are to give the same previous notice for these two general meetings, as is given for ordinary general meetings of the Commissioners of Supply.*

Any five, and in the small shires of Kinross, Clackmannan, and Cromarty, any three, whether commissioners or justices, or consisting of both, are a quorum. This meeting may adjourn from time to time. It may choose clerks, surveyors, and other officers for putting the laws in execution. This meeting is empowered "to set down a particular list of highways, bridges, and ferries, within their bounds, and to divide the paroches

* Hucheson's Treatise, &c. vol. ii. p. 485.

of the said bounds, as they lie nearest to the several highways to be repaired, and as they may have the most equal burdens; and to appoint such of their number, or others, overseers of such parts and portions of the said highways as are most convenient and nearest to their ordinary residence; and to nominate such of their number as they see fit, to survey and give an account of the highways, bridges, and ferries, unto the rest; with powers to them to appoint meetings from time to time, till the survey, list, and division of the said highways be closed.*

For repairing the roads, the justices and Commissioners of Supply are intrusted with the charge of the statute labour.†

This system of managing the highways having been found very defective, most of the counties of Scotland have obtained acts of parliament for placing the roads under the government of trustees. The following are the principal provisions of these acts.‡

The governing authority for a county is vested in trustees. Every person in the county is appointed a trustee, who is possessed of a certain

* Act 1669, c. 10. † Act 1617, c. 8.

‡ See in Appendix, No. V. the principal clauses of the Act for the county of Forfar.

property; also the eldest sons of such persons; one guardian or trustee of minors possessing such property; every person in the commission of the peace; the provost and two eldest baillies in each royal burgh in the county; the sheriff depute, and sheriff substitute.

The county is divided into districts.

The trustees residing in each district manage the roads contained in it.

The district meeting prepares annually a state and estimate for the general meeting.

The general meeting has power to order an assessment to be made on the occupiers of lands, not exceeding a prescribed amount.

The proceedings of the trustees of the districts at their meetings, are subject to the direction and control of the general meetings.

The trustees of the district meetings appoint surveyors of the roads in their districts, with salaries.

Sufficient powers are given to the trustees for obtaining land and materials for making, widening, and repairing roads, and building bridges.

This system of managing the highways of Scotland has the following advantages over the English system of parish management:—

1st. A more efficient governing authority is provided.

2dly. The obstacle to a uniform and efficient management of the roads which the small divisions of parishes occasion, is obviated by giving the general management of all the roads of a county to the general meetings of the trustees.

3dly. The funds for maintaining the roads are derived from a regular assessment on the lands, instead of by statute labour.

4thly. The surveyors are appointed permanently, and with fixed salaries.

The experience of the manner in which this Scotch system has worked, fully establishes its great superiority over the old Scotch system, which still exists in some counties, and over the English parish system; and leads to the conclusion that it is expedient to make it universal in Scotland, and substitute it in England instead of the English system.

IRISH ROADS.

There are but few turnpike roads in Ireland. A report of the committee of the House of Commons, of the session of 1832, shows how defective they are.

The trustees of these roads should be placed under the control of the new Board of public Works in Dublin, in the same way as has been

proposed with respect to placing the turnpike roads of England under the Commissioners of Land Revenue.

It has been mentioned in the introduction, that the roads which are not turnpike in Ireland were placed under the management of the county grand juries in the year 1763, and what has been the general result of this plan.

The main defects of this plan consist in the unfitness of a grand jury as a governing authority, and in creating as many road overseers as there are applicants for money for making and repairing roads.

The grand jury is not a proper governing authority, because the persons who compose it do not represent the interests concerned in road affairs; and because they can meet but twice a year, and are then occupied with the duties belonging to the criminal prosecutions at the assizes.

By making the applicants for money to be expended on roads the overseers of the expenditure of it, the business of road management falls into the hands of persons ignorant of the proper manner of conducting it. At the same time, another evil arising from this plan is, that it is next to impossible to control the application of the money granted from the roads, so as to

prevent it from being embezzled by the overseers.

To remedy these defects in principle of the Irish road law, no more safe or effectual proceeding could be adopted than the introducing of the modern Scotch system of county road management. The substituting of county trustees for grand juries, and of surveyors for the present tribes of overseers, would provide a remedy of what is wrong in the Irish system.* But unless a more correct moral principle shall also be substituted by purer habits in place of that which has hitherto prevailed among Irish grand juries, with regard to the money levied for the purposes of the roads, neither this proposed alteration, nor any other that the legislature can make, will be followed by any general improvement.

The Irish road act just passed is not founded on any sound principle. The grand juries are continued as the governing authorities. The addition of rate payers to the magistrates to form special sessions for investigating applications for presentments for money, previous to their being laid before the grand juries, with

* The author received instructions, a few years ago, from the grand jury of the Queen's County, to bring a bill into parliament for the management of the roads of that county, on the Scotch plan.

powers to reject them, will lead to an excess of parsimony, and be productive of the ruin of the roads. The clause that requires the tenders of the lowest bidders for contracts to be accepted, will throw all the road work into the hands of schemers destitute of capital, skill, and honesty. It is fortunate that the act contains a clause to postpone its coming into operation till after the next session of parliament, for it will be found, on consideration, to be wholly unfit for establishing a proper plan of road management. Under these circumstances, it is highly expedient deliberately to examine whether any valid objection can be urged to the introducing of the Scotch plan into Ireland, which experience has proved to work so well, in place of continuing the attempt to mend the Irish grand jury system.

APPENDIX.

APPENDIX, No. I.

Description of the Road Indicator, an Instrument invented by Mr. Macneill for the Purpose of ascertaining the Draught of Carriages, and the comparative Merit of Roads; with Tables of Experiments, etc.*

This instrument, which is described in the following pages, is capable of being applied to several very important purposes in road engineering, amongst which are the following:—

First, It affords the means of ascertaining the exact power required to draw a carriage over any line of road.

Secondly, It can be applied to compare one line of road with another, so as to determine which of them is the best, and the exact amount of the difference, as regards horse power, both for slow and fast coaches.

Thirdly, The comparative value of different road surfaces may be determined with great exactness.

Fourthly, It affords the means of keeping a registry, in a most accurate manner, from year to year, of the state of a road, showing its improvement or deterioration, and the exact parts in which such improvement or deterioration have taken place.

* This paper has been furnished by Mr. Macneill.

PRACTICAL EXAMPLES EXPLANATORY OF THE FOREGOING STATEMENT.

1st, Let it be required to determine the expense of working a four-horse coach over the line of road from —— to ——, at a velocity of ten miles an hour. Suppose the instrument has been run over the road, and that it has been found that the average power required to draw a four-horse coach over the whole line amounts to 350 lbs., and the distance equal to twelve miles. Let the average power which a horse should exert for eight miles a day, with a velocity of ten miles per hour, be assumed equal to 60 lbs., then $60 \times 8 = 480$ lbs., raised one mile in the day; and taking the daily expense of a horse equal to six shillings, we have 480 lbs. : 6*s.* : : 1 lb. : ·15, the expense of horse power, exerting a force of one pound over one mile. Thence, $350 \times {\cdot}15 \times 12$ miles $= 630$ pence, or 2*l.* 12*s.* 6*d.*, the expense of horse power required to work a four-horse coach per day over such a road.

2dly, Suppose it be required to determine whether it is more expensive to work a coach over the stage from A to B, or over the stage from C to D, both stages being exactly ten miles, and horse keep the same in both districts. Let the instrument be run over both stages, and suppose the average power thus determined to be 280 lbs. on the stage from A to B, and 320 lbs. on the stage from C to D, the difference is $320 - 280 = 40$ lbs.; and this difference will amount to $40 \times 10 \times {\cdot}15 = 5$ shillings, in horse power, in favour of the stage from A to B.

Again: suppose the stage from A to B, which is ten miles in length, to be compared with the stage from E to F, which is only eight miles in length, but more hilly, or having a worse surface. Let the instrument be run

over each stage as before, and suppose the average power from E to F to be found equal to 500 lbs., whilst the average power over the stage from A to B is only 320 lbs., as this stage is ten miles in length, the expense of working over it will be $320 \times 10 \times \cdot 15 = 576$ pence; and the expense over the stage from E to F will be $500 \times 8 \times \cdot 15 = 600$ pence; from which it will be seen that less expense will be required to draw the carriage from A to B than from E to F, although the distance from E to F is two miles shorter than from A to B; and that the difference of expense will be $600 - 576 = 24$ pence, or two shillings per day for a four-horse coach.

3dly, Suppose it be required to determine the best surface on different parts of a road, which has been constructed on different principles or repaired with different descriptions of road materials. Let the instrument be run over each portion of the road, and the average power noted — also the rates of inclination, as shown by the instrument, or a spirit level — then reduce the average draught over each rate of acclivity to what it would be if it was horizontal; the comparison of the corrected draughts will show the friction arising from the surface in each case. Thus, suppose the average draught over a portion of the road, which has been repaired with gravel, and which rises 1 in 20, to be 250 lbs. The correction for 1 in 20 is 39·2 lbs. The friction of the surface and axles is therefore $250 - 39{\cdot}2$, or 210·8 lbs. (See 7th Report of Parliamentary Commissioners of the Holyhead and Liverpool Roads, published by order of the House of Commons, January, 1830.)

In the same way, suppose the draught over another portion of the road which rises 1 in 10, but which has been repaired with granite, is found to be 260 lbs. The

correction for 1 in 10 is 78·4 lbs., therefore the friction of the surface, or what it would be if it was horizontal, would be 260—78·4, or 181·6 lbs. only; the difference between this and the gravel surface will therefore be 210·8—181·6, or 29·2 lbs., which is equal to a saving of 4½ pence for every horse drawing over a mile of such a road, as compared with the other.

4thly, The most important and useful application of the instrument is, perhaps, that of being able to ascertain with accuracy and precision the state of any road, from time to time, as regards its surface; and the state of repair in which it has been kept.

The following table, or yearly registry of a quarter of a mile of road, will show this more clearly. The numbers in the column represent the draught, or horse power, taken at every ten yards. Thus, in the first column of the year 1829, the draughts were in summer 20, 30, 25, &c., and in the second, or winter column of the same year, the corresponding draughts on the same identical part of the road are found to be 35, 35, 30, &c.: these columns added up, and divided by the number of observations, give 44·5 lbs., for the mean summer draught, and 49·45 lbs. for the mean winter draughts, over this quarter of a mile. By following the same process in the following year, viz. in 1830, the mean summer draught was found to be 35·6 lbs., and the mean winter draught 40·36 lbs., showing that the road had been improved in the course of the year very considerably; and by a reference to the numbers in the columns on the same horizontal lines with each other, it will be found the improvement has been general, throughout the whole distance. In the next year, 1831, it will be seen that the average power in summer is

40·52 lbs., and in winter 46·5 lbs., which shows the road is not so good as it was in the preceding year, 1830, but better than it was in the first year, 1829. Again, in the year 1832, it is found that the average summer draught is 53·6 lbs., and the winter draught 63·18 lbs.: by comparing these numbers with any of the preceding years, it will at once be evident that the road has become worse; and by a reference to the figures in the column, it will be seen that it is defective in every part as compared with the preceding years, but more especially so near the end, where the draught in summer varies from 60 to 85 lbs., and in winter from 75 to 95 lbs.; whereas, in 1830, two years before, the draughts in summer, over the same part of the road, varied from 35 to 38 lbs. only, and in winter from 46 to 40 lbs. The instrument, therefore, shows not only that the road has been getting generally worse, but it points out the particular parts, and the exact amount of deterioration; thus enabling the proper authorities to say that the road has *become worse, the amount of the deterioration*, and the *exact part of the road where such deterioration has taken place.*

The public advantages to be derived from such a system of road inspection would probably be very great. It would show not only where the best plan of repairing roads has been followed, and point out where there are good and bad surveyors, but it would also show if the money of the trust is improperly applied or wasted on any line of road; and it will enable trustees, who let the repairs of their roads by contract, to determine whether or not the contractors have done their duty, and kept the road in the same state of repair as at first, or whether they had improved it, or suffered it to become defective.

There are many other uses to which the instrument may be applied, but the foregoing are the principal ones.

Mr. Telford, in his Report to the Parliamentary Commissioners of the Holyhead and Liverpool Roads, speaking of this instrument, states, "I consider Mr. Macneill's invention, for practical purposes on a large scale, one of the most valuable that has been lately given to the public."

Mr. Babbage, the Lucasian Professor of Mathematics in the University of Cambridge, in his valuable and well-known work on the Economy of Machinery and Manufactures, in considering the injury which roads sustain from various causes, states, "As connected with this subject, and as affording most valuable information upon points in which, previous to experiment, widely different opinions have been entertained; the following extract is inserted from Mr. Telford's Report on the State of the Holyhead and Liverpool Roads. The instrument employed for the comparison was invented by Mr. Macneill, and the road between London and Shrewsbury was selected for the place of experiment. The general results, when a waggon weighing 21 cwt. was used on different sorts of roads, are as follow: —

	lbs.
1. On well-made pavement the draught is -	33
2. On a broken stone surface, or old flint road -	65
3. On a gravel road - - - - -	147
4. On a broken stone road, upon a rough pavement foundation - - - - -	46
5. On a broken stone surface, upon a bottoming of concrete formed of Parker's cement and gravel	46."

Specimen of the Manner in which it is proposed to keep a Registry or Journal of the State of Repairs of any Road.

FROM LONDON TO .

First Quarter of First Mile.

Dist.	1829.		1830.		1831.		1832.		1833.		1834.	
Yards.	Summer.	Winter.	Summer.	Winter.	Summer.	Winter.	Summer.	Winter.	Summer.	Winter.	Summer.	Winter.
10	20	35	15	30	15	32	25	40				
20	30	35	25	30	27	32	35	40				
30	25	30	20	26	22	28	30	35				
40	28	33	21	28	24	30	35	40				
50	29	33	22	28	26	30	40	50				
60	35	39	26	29	30	35	45	60				
70	30	35	22	25	24	27	35	55				
80	30	36	23	26	25	28	40	45				
90	35	40	25	35	27	37	40	50				
100	40	43	30	36	32	38	45	55				
110	45	46	35	38	37	40	50	55				
120	50	55	40	45	42	47	60	65				
130	50	54	40	44	42	46	70	75				
140	50	55	40	46	42	48	55	75				
150	55	58	50	48	52	50	60	70				
160	52	56	43	41	45	45	55	56				
170	50	54	40	45	42	48	60	70				
180	51	55	46	45	48	47	60	75				
190	53	58	45	46	47	48	65	68				
200	55	60	50	52	52	55	65	70				
210	56	60	50	55	52	58	65	75				
220	55	60	45	55	50	60	65	75				
230	50	55	45	40	48	45	60	65				
240	50	55	45	35	47	37	55	75				
250	48	50	38	40	40	44	50	60				
260	45	50	35	40	38	45	55	65				
270	40	45	30	40	35	45	45	50				
280	40	45	36	40	40	45	50	60				
290	40	45	35	35	38	40	55	60				
300	46	50	36	40	40	44	50	60				
310	44	50	32	45	40	45	55	65				
320	43	48	31	45	35	50	50	60				
330	42	50	30	40	35	45	55	60				
340	40	46	30	40	35	45	50	60				
350	45	49	38	45	40	50	46	56				
360	50	55	40	45	45	50	55	65				
370	50	56	40	46	45	50	55	70				
380	51	58	40	48	44	49	60	70				
390	52	58	46	48	50	55	50	65				
400	53	56	40	46	45	55	60	70				
410	50	55	35	45	50	60	60	75				
420	50	54	36	40	50	70	80	85				
430	55	58	38	40	60	80	80	90				
440	50	58	38	40	80	88	85	95				
Total	1958	2176	1567	1776	1783	2046	2361	2780				
Horse power	44·5	49·45	35·6	40·36	40·52	46·5	53·6	63·18				

DESCRIPTION OF THE INSTRUMENT.

The framework is of wrought iron, about two feet six inches long, and eighteen inches wide. In this frame a dynamometer and brass cylinder are placed; the dynamometer is connected by its arm to one side of the frame, and the cylinder is secured in the frame by trunnions, which are cast on it, and which turn in a circular hoop or belt, firmly screwed to one side of the frame, and a bar running across it. The dynamometer, or weighing-machine, which forms part of the instrument, was introduced, some years ago, by Mr. Marriott; and as it is now so generally known, being used in mail-coach and other offices instead of the common steelyard, or scales requiring weights, it is needless to describe it here. On my applying the weighing-machine, in its simple form, to measure the draught of carriages, I found that the index vibrated so quickly, and over so large an arch of the circle, that it was impossible to observe the point indicating the force of draught; for a horse exerts his power by a succession of impulses, or strokes of his shoulders against the collar, at every step he makes, and not by a constant uniform pull, as is generally supposed. To remedy this inconvenience, and do away with the vibrations, I applied a piston, working in a cylinder full of oil, and connected with the dynamometer in such a manner that when any power or force is applied to it, so as to carry round the index, the piston is at the same time moved through the fluid. The connection of the dynamometer with the cylinder is by means of a lever working on a pivot; the arms of the lever are of unequal length; the tail-piece of the dynamometer is connected with the short arm, at a distance of two inches from the centre, or fulcrum, by means of a

pivot-joint at precisely the same distance from the fulcrum; a flat bar of iron is connected with the longer arm, by a joint similar to that by which the tail-piece is connected with the short arm, so that any power or weight applied to the bar will produce the same effect on the index as if the power was applied directly to the tail-piece of the dynamometer; this bar passes over a friction roller, and to it the power of the horses is applied when in use, by means of traces and a bar, as in the ordinary mode of draught. At the extremity of the long arm, the piston rod is connected by a joint similar to the others; the piston-rod, after passing through a stuffing-box in the cap of the cylinder, is screwed into a piston, or circular plate of thin brass perforated with small holes; and out of one part of the circumference a square notch is cut, the use of which will be hereafter described.

By this construction the resistance of the fluid to the piston, which acts at the extremity of the long arm of the lever, prevents its turning round the fulcrum to the extent it otherwise would do when it is acted upon by any sudden impulse applied to the bar; it will, however, move over a space proportioned to the intensity of the force applied; and if the pulls follow each other in rapid succession, the piston will move slowly out, and the index will turn round steadily and uniformly, until the power is balanced by the spring of the dynamometer, at which time the index will point out on the dial very nearly the weight or power which is equivalent to the draught.

The divisions on the dial-plate of the dynamometer decrease from zero upwards, in order to compensate for the increased force which the spring exerts in proportion as it is wound up: in consequence of this, the index

does not pass over equal spaces when equal forces are applied in different states of tension of the spring; the piston, therefore, will not pass through equal spaces in the cylinder, and the vibrations would consequently be greater in the higher numbers, because, the velocity of the piston being less, its resistance through the fluid will be less, at the same time the power opposed to it is greater. To obviate this, and make the index equally steady on all parts of the dial, a narrow slip of brass, formed into an inclined plane, is soldered to the inside of the cylinder, parallel to its axis, the largest part being at that end of the cylinder towards which the piston rises when the index moves towards the greater power.

The notch, which was before mentioned as cut in the side of the piston, exactly corresponds in size with the largest part of this inclined plane, so that when the piston is at the upper end of the cylinder, the notch is completely filled up by the inclined plane; on the contrary, when the piston is at the lower end of the cylinder, the notch is open: by this contrivance the aperture through which the fluid is obliged to pass, as the piston moves from the lower end of the cylinder to the higher, is gradually contracted, and, of course, the resistance of the piston through the fluid gradually increases, and compensates the increased power of the spring, rendering the vibrations nearly uniform from the lowest to the highest power. This compensation is analogous to that by which the fusee regulates and gives uniform power to the main-spring of a watch.

METHOD OF USING THE INSTRUMENT.

To preserve the instrument from warping, bending, or other injury, it is embedded in a solid block of elm,

which can be screwed or clamped to any carriage; the swingletree is hooked into the eye of the draught-bar; the shafts or pole of the carriage may remain in their ordinary position, but care must be taken that no part of the moving power is communicated to the carriage, except through the agency of the instrument. The draught of a carriage over any portion of ground is ascertained as follows:—*

One assistant walks along the side of the carriage, and observes the weight, or force, shown by the index on the dial; at every step he calls out the numbers, which another assistant writes down in a book; these numbers are then added together, and the sum divided by the number of observations that have been made: the quotient will be the mean power, or draught, required to draw the carriage over that portion of the road. Thus, for instance, the instrument was fixed on the fore carriage of a common four-wheeled waggon, and two horses attached to it; it was then drawn over the pavement in Piccadilly, between the Duke of Devonshire's house and the corner of Dover Street; the numbers given by the index were, 50 lbs., 45 lbs., 50 lbs., 50 lbs., 55 lbs., 50 lbs., 45 lbs., 40 lbs., 45 lbs., 45 lbs., 50 lbs., 45 lbs., 50 lbs., 55 lbs.; the sum of these is 670 lbs., which, divided by 14, the number of observations, gives $48\frac{1}{2}$ lbs. for the mean force which the horses must exert to draw the empty waggon over that part of Piccadilly pavement.

As the street in that part rises 1 foot in 156 feet, it

* Since this was written, the instrument has been much improved by Mr. Macneill: it is now mounted in a light phaeton, and, besides marking the draught at every ten or twenty yards, it points out the distance run, and the rates of acclivity or declivity on every part of the road.

is evident that the draught is greater than if the street was horizontal. To ascertain what it would be if it was horizontal, it is necessary to apply a correction to the draught actually shown by the instruments.

By theory we know that the power required to retain a carriage on an inclined plane, bears the same proportion to the weight of the carriage and its load, that the height of the inclined plane bears to its length; but as the mean velocity of the matter in the wheels of a carriage is different from the velocity of the axis up the inclined plane, another correction would be necessary to get the motive power up the plane; and to persons not acquainted with the subject, the final result might appear doubtful. To alleviate every objection of this kind, I had a platform of timber erected, over which the same waggon that was used in the experiments on roads, was drawn at different rates of inclination; and the power required to draw it up the inclined plane, with a uniform velocity of two miles and a half per hour, in each case, was carefully determined by dead weights passing over pulleys. By this means the correction for several rates of inclination was practically ascertained (without having recourse to theory or calculation), and the table of correction which I have inserted was formed for all slopes usually found on turnpike roads.

By this table, the correction for a slope of 1 in 156, is found to be 15 lbs.; hence the horizontal draught of a waggon over the paved surface between the Duke of Devonshire's house and Dover Street, will be 48½, less 15½, or 33 lbs.

In this way the surface of the whole road between London and Shrewsbury has been tried, the results of which are given in the following tables.

OBSERVATIONS ON THE USE OF THE INSTRUMENT.

A road with a smooth and uniform surface, which is merely preserved in that state by raking, appears to the generality of persons who travel over it to possess all the requisites of a good and perfect road, as such persons have no means of judging of the power necessary to draw carriages over it, or the exertion required from the horses; but by means of this instrument that power can be ascertained, and, consequently, the comparative merit of any line of road can be determined with absolute certainty, and the experiments made with the instrument will show how very important it is to the country to have the public roads constructed and maintained on true principles.

In some instances metal rails are laid on the sides of turnpike roads, with the same undulations and rates of inclination as the road; yet on these railroads a horse will usually perform as much work as five or six horses will do on the common road. This great difference in the useful effect of horses can alone be attributed to the friction of the road surface exceeding that of the metal rails; for the friction of the axles of the waggon will be nearly similar, and the resistance of gravity, arising from the inclinations are, in this case, the same; hence the superiority of the one road over the other depends entirely on the surface.

The greatest resistance which a horse has to encounter, when in draught on turnpike roads, arises from gravity, which begins to act the moment the road ceases to be horizontal; and when the inclination exceeds one in thirty, which it often does, the additional power required is very great, as may be seen by the table of corrections; at the same time, the power of the horses is from the same cause much diminished. It is, there-

fore, the more necessary that the surface of the hills should be hard, solid, and composed of such materials as the wheels of carriages cannot penetrate.

By making experiments with this instrument on every part of a turnpike road, both in summer and winter, and forming an exact table, showing the resistance of the surface, and the materials with which it is repaired, a complete register would be had of the state of the road; and any improvement or falling-off in the general management of the repairs of each part would be clearly perceptible, as also the amount of such improvement, or the reverse.

The following is an extract from the Appendix of this Report, containing Mr. Macneill's description of the experiments referred to: —

EXPLANATION OF TABLE, NO. 3.*

For the purpose of ascertaining the draught up different hills, with different velocities, the instrument was attached to a common stage coach, which weighed 18 cwt., exclusive of seven passengers. Stations were marked out on different parts of the road, of which the inclinations and the lengths were accurately determined, and the time of passing over each was ascertained by means of a stop-watch.

The results of these experiments are detailed in this table.

The first column contains the number of each experiment; the second the rate of inclination of the hill; the third, the number of observations made on each; the fourth, the length of the hill or inclined plane, in feet;

* Table No. 1. contains a detailed account of the experiments made on the Holyhead Road; and Table No. 2. the corrections for gravity according to the inclinations of the Road.

the fifth, the number of seconds in which the carriage was drawn up the hill; the sixth, the corresponding velocity in feet per second; the seventh, the velocity in miles per hour, calculated to the nearest quarter; and the eighth column contains the corresponding draughts, or force applied, in pounds.

Thus, in the first line of the first experiment, where the inclination of the hill was one in fifteen and a half, and the velocity three miles and a half per hour, the draught was 271 lbs.; and when the velocity was increased to twelve miles per hour, as shown in the fourth line of the same experiment, the draught was also increased from 271 to 325 lbs.

The part of the roads elected for these trials was of an uniform surface, the resistance of which was previously ascertained by drawing a waggon over it, to be an average between the worst and most improved parts of the Holyhead road; and although the velocities are not so varied, or so high as might be wished, yet several conclusions may be drawn from these experiments, of considerable importance in road engineering; one of which is, that the draught of a stage coach on a common turnpike road increases in a less ratio than the velocity increases, and not as the square of the velocity, which many persons have supposed, as is found to be the case in the steam carriage on a rail-road. From this it appears, that the resistance, arising from friction, of a steam carriage on a rail-road, and the resistance of a stage coach on a good turnpike road, are governed by the same laws of motion; and that whatever advantage may be gained by a quick transport of passengers, by means of a steam coach on the former, may also, probably, be attained by the same means on a well-made turnpike road.

TABLE III.

No. of Experiments.	Rates of Inclination.	No. of Observations.	Distance in Feet.	Time in Seconds.	Velocity in Feet per Second.	Velocity in Miles per Hour.	Draught of Stage Coach in lbs.
1	2	3	4	5	6	7	8
1	One in 15½	32 22 13 13	576	115″ 111 47 33	5·0 5·2 12·2 17·4	3½ 3½ 8½ 12	271 276 298 325
2	One in 19	48 17 24 32	741	178 82 80 66	4·1 9·0 9·3 11·2	2¾ 6 6¼ 7½	252 290 293 303
3	One in 20	35 34 16 22	750	136 126 81 76	5·5 5·9 9·2 9·8	3¾ 4 6¼ 6¾	253 263 272 280
4	One in 21½	16 16 8 7	294	58 50 33 30	5·1 5·9 8·9 9·8	3½ 4 6 6¾	237 245 258 264
5	One in 23	29 23 13 13	522	99 78 55 49	5·3 6·7 9·5 10·7	3½ 4½ 6½ 7¼	226 233 243 250
6	One in 23½	45 22 18 —	1032	189 127 88 83	5·5 8·1 11·7 12·4	3¾ 5½ 8 8½	230 240 248 253

Table III.—*continued.*

No. of Experiments.	Rates of Inclination.	No. of Observations.	Distance in Feet.	Time in Seconds.	Velocity in Feet per Second.	Velocity in Miles per Hour.	Draught of Stage Coach in lbs.
1	2	3	4	5	6	7	8
7	One in 26. Paved bottom, Hartshill stone surface.	16	387	69″	5·6	$3\frac{3}{4}$	200
		20		68	5·7	$3\frac{3}{4}$	202
		13		42	9·2	$6\frac{1}{4}$	215
		12		28	13·8	$9\frac{1}{2}$	223
8	One in $26\frac{1}{2}$. Not paved, limestone surface.	27	570	103	5·5	$3\frac{3}{4}$	221
		19		102	5·6	$3\frac{3}{4}$	220
		14		56	10·2	7	230
		12		47	12·1	$8\frac{1}{4}$	236
9	One in 28	26	654	123	5·3	$3\frac{1}{2}$	197
		28		110	5·9	4	204
		13		68	9·6	$6\frac{1}{2}$	211
		12		55	11·9	8	218
10	One in $30\frac{1}{2}$	15	300	58	5·2	$3\frac{1}{2}$	161
		12		52	5·8	4	174
		9		30	10·0	$6\frac{3}{4}$	187
		6		23	13·0	9	210
11	One in 33	38	711	129	5·8	4	153
		15		90	7·9	$5\frac{1}{2}$	175
		17		80	8·9	6	182
		15		55	12·9	$8\frac{3}{4}$	198
12	One in $34\frac{1}{2}$. Patches of new stone, not worked in or consolidated.	30	534	95	5·6	$3\frac{3}{4}$	186
		11		65	8·2	$5\frac{1}{2}$	196
		10		55	9·7	$6\frac{1}{2}$	200
		13		43	12·4	$8\frac{1}{2}$	214

Table III.—*continued.*

No. of Experiments.	Rates of Inclination.	No. of Observations.	Distance in Feet.	Time in Seconds.	Velocity in Feet per Second.	Velocity in Miles per Hour.	Draught of Stage Coach in lbs.
1	2	3	4	5	6	7	8
13	One in $38\frac{1}{2}$. Sub-pavement, surface quartz stone.	19	384	68″	5·6	$3\frac{3}{4}$	146
		18		65	5·9	4	150
		13		41	9·4	$6\frac{1}{2}$	167
		10		30	12·8	$8\frac{3}{4}$	170
14	One in 39. No sub-pavement, nine inches of lime-stone.	16	543	84	6·5	$4\frac{1}{2}$	180
		17		80	6·8	$4\frac{3}{4}$	183
		16		63	8·6	$5\frac{3}{4}$	212
		13		60	9·1	$6\frac{1}{4}$	215
15	One in 57. No sub-pavement, quartz stone surface.	21	552	97	5·7	$3\frac{3}{4}$	150
		12		85	6·5	$4\frac{1}{2}$	153
		13		66	8·3	$5\frac{3}{4}$	160
		10		39	14·1	$9\frac{1}{2}$	168
16	One in $63\frac{1}{2}$. No sub-pavement, six inches of lime-stone.	21	525	89	5·9	4	147
		24		88	6·0	4	147
		13		47	11·2	$7\frac{1}{2}$	182
		13		41	12·8	$8\frac{3}{4}$	202
17	One in 118	18	603	107	5·6	$3\frac{3}{4}$	134
		26		91	6·6	$4\frac{1}{2}$	140
		11		60	10·0	$6\frac{5}{4}$	146
		17		50	12·1	$8\frac{1}{4}$	153
18	One in $137\frac{1}{2}$	35	741	122	6·1	$4\frac{1}{4}$	133
		18		95	7·8	$5\frac{1}{4}$	136
		18		75	9·9	$6\frac{3}{4}$	140
		18		62	12·0	$8\frac{1}{4}$	150

Table III.—*continued.*

No. of Experiments.	Rates of Inclination.	No. of Observations.	Distance in Feet.	Time in Seconds.	Velocity in Feet per Second.	Velocity in Miles per Hour.	Draught of Stage Coach in lbs.
1	2	3	4	5	6	7	8
19	One in 156 rise	44	861	161″	5·4	3¾	128
		25		130	6·6	4½	133
		20		85	10·1	7	139
		22		61	14·1	9½	145
20	One in 156 fall	41	861	205	4·2	2¾	82
		15		84	10·2	7	95
		13		57	15·1	10¼	100
		16		54	15·9	10¾	105
21	One in 245 rise	28	648	105	6·2	4¼	125
		16		70	9·2	6¼	128
		15		48	13·5	9¼	131
		12		45	14·4	9¾	138
22	One in 245 fall	39	648	114	5·7	4	96
		22		103	6·3	4¼	100
		23		75	8·6	6	107
		11		47	13·8	9½	117
23	One in 600 rise	42	993	108	9·2	6¼	112
		25		103	9·7	6½	114
		20		72	13·8	9½	122
		23		65	15·3	10½	130
24	One in 600 fall		993	177	5·6	3¾	100
				147	6·8	4½	110
				100	10·0	6¾	115
				64	15·5	10½	127

Table of the General Results of the Experiments made with a Stage Coach, on the same Description of Road; but on different Rates of Inclination, and with different Rates of Velocity.

Rates of Inclination.	Rates of Travelling.	Force required.
1 in 20	6 miles per hour	268 lbs.
1 in 26	6 - -	213 lbs.
1 in 30	6 - -	165 lbs.
1 in 40	6 - -	160 lbs.
1 in 600	6 - -	111 lbs.
1 in 20	8 miles per hour	296 lbs.
1 in 26	8 - -	219 lbs.
1 in 30	8 - -	196 lbs.
1 in 40	8 - -	166 lbs.
1 in 600	8 - -	120 lbs.
1 in 20	10 miles per hour	318 lbs.
1 in 26	10 - -	225 lbs.
1 in 30	10 - -	200 lbs.
1 in 40	10 - -	172 lbs.
1 in 600	10 - -	128 lbs.

From this table it will be seen that the power required, when the velocity is ten miles an hour, to draw a carriage up an inclined plane which rises one in twenty, may be taken at three times as much as is required to draw it on a level road.

If we suppose the power which a horse usually exerts in mail and fast stage coaches to be equivalent to a constant pull of 37 lbs.* over ten miles in a day, with a

* This is the power assigned by Mr. Tredgold, in his work on Railways, as that which a horse should exert working with a velocity of ten miles an hour; which, though sufficiently correct, as in the present instance, for a measure of comparison, should not be considered as a fixed standard of the power of a horse working at the velocity of ten miles an hour; as the formula which Mr. Tredgold has used appears to be founded on a limited number of experiments.

velocity of ten miles an hour, the effect will be equal to 651,200 lbs.; for 1760 × 10 = 17,600 yards in 10 miles, and this sum multiplied by 37 lbs. equals 651,200 lbs. drawn over one yard in the day; which number may be taken as a standard for horse power in comparing one line of road with another.

If, on this principle, we know the average draught over any line of road, and the length of that road in yards, we at once know the horse power to which it is equivalent, and, consequently, can compare it with any other line.

Thus, the average draught on the old road between Barnet and South Mims, multiplied by the length of that road in yards, is equal to 165,320; by the new line, the average draught multiplied by its length in yards is 139,028 *; the difference between this and the old road is 26,292, which, divided by 651,200, the power of one horse, gives ·04 part of a horse power; this multiplied by 500, the number of horses travelling over the road each day, and supposing each horse to be worth five shillings per day, the saving by making the new road will amount to 5*l.* per day, or to 1800*l.* annually.

The result derived from this calculation depends not on any theory or abstruse calculation; it is a matter of *fact, and cannot be disputed;* and is, perhaps, one of the most useful practical applications of the Road Instrument; for without it the most refined and difficult application of algebra to the plans and sections of the above roads would only give an approximate value, as the state of the surface could not be brought into the calculation, *except by guess*, and this would be little better than judging by the sections, as heretofore practised, without any decided or fixed principle.

* See the annexed table of the actual draught on every twenty yards of this road.

BARNET AND SOUTH MIMS, OLD ROAD.

5th July, 1833. *State of the Surface.* 3 miles, 352 yards.

	Going from Barnet to Mims.								Going from Mims to Barnet.							
Distance.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.
1	23	7	30	14	12	10	25	10	50	0	32	85	0	65	25	18
2	30	10	35	13	3	5	40	8	85	0	23	95	0	55	20	18
3	27	8	35	20	2	7	40	0	75	0	50	100	0	80	23	14
4	21	3	30	32	3	10	58	0	80	0	85	73	0	45	10	14
5	21	2	24	43	2	12	30	20	70	0	10	70	0	25	18	17
6	15	4	7	25	7	6	50	10	62	0	0	55	0	27	40	24
7	12	5	38	20	0	6	55	3	50	0	0	55	0	35	52	20
8	15	5	8	41	0	10	60	0	55	0	7	70	0	45	55	28
9	20	3	28	40	0	10	70	5	50	0	21	45	7	45	48	15
10	10	5	24	56	0	10	75	10	50	0	16	45	3	27	37	17
1 F.	19·4	5·2	25·9	30·4	2·9	8·6	50·3	6·6	62·7	0	24·4	69·3	1·0	44·9	32·8	18·5
11	20	6	30	48	0	25	90	25	35	10	15	40	12	10	28	18
12	16	10	10	52	0	14	60	24	30	0	18	30	10	16	30	18
13	20	10	0	45	0	10	70	10	30	0	17	20	10	32	32	20
14	23	0	0	50	0	15	100	0	35	0	12	25	12	50	30	20
15	12	0	0	45	0	30	80	0	40	0	10	45	15	40	30	17
16	13	4	5	48	0	47	50	0	50	12	20	55	15	21	30	22
17	16	5	18	60	0	60	60	0	25	18	20	50	20	17	18	19
18	22	20	10	75	0	30	50	0	30	15	25	40	15	37	30	12
19	23	17	0	75	0	0	50	0	65	25	20	45	33	27	27	22
20	20	30	0	80	0	0	65	0	73	15	35	55	30	40	20	20
2 F.	18·5	10·2	7·3	57·8	0	23·1	67·5	5·9	41·3	9·5	19·2	40·5	17·2	29·0	27·5	18·8

21	27	30	0	75	0	0	52		60	3	40	33	30	32	20	14
22	22	25	0	55	0	15	32		15	13	40	38	37	40	22	16
23	16	34	0	52	0	20	5		0	5	38	23	45	55	13	
24	22	17	0	50	0	16	0		0	7	40	10	55	57	20	
25	28	18	0	60	0	25	0		0	2	47	4	60	50	18	
26	26	17	0	85	3	13	0		0	3	50	8	75	30	13	
27	31	23	0	45	0	14	0		0	0	45	27	90	30	17	
28	25	22	0	4	0	13	0		0	10	40	45	80	40	15	
29	23	12	0	0	0	20	20		0	10	42	45	80	20	7	
30	20	14	0	10	0	22	13		0	25	50	40	95	24	8	
3 F.	24·0	21·2	0	43·6	0·3	15·8	12·2	6·25	7·5	7·8	43·2	27·3	64·7	37·8	15·3	3·0
31	20	10	0	12	0	12	45		0	33	55	25	95	22	10	
32	16	7	0	15	0	20	37		0	28	60	35	115	16	14	
33	21	4	0	10	0	35	45		8	20	40	40	98	18	10	
34	18	37	0	3	0	50	45		23	15	63	30	100	4	8	
35	17	28	0	5	0	25	50		55	12	60	7	80	5	18	
36	16	18	0	20	0	40	50		57	17	55	0	60	18	14	
37	12	7	15	24	0	45	55		50	15	85	0	65	20	18	
38	10	3	9	47	0	40	50		57	24	90	0	80	20	18	
39	4	4	16	20	3	40	65		60	20	75	0	70	22	12	
40	10	10	7	9	7	45	40		20	14	90	0	65	38	18	
4 F.	14·4	12·8	4·7	16·5	1·0	35·2	48·2		41·0	19·8	67·3	13·7	82·8	18·3	14·0	10·4
Mean of half Miles.	19·07	12·35	9·47	37·07	1·05	20·67	44·42		55·62	92·7	38·52	37·7	22·55	32·5	22·4	
	15·71		23·27		10·86				32·44		38·11		27·50			

BARNET AND SOUTH MIMS, NEW ROAD.

4th July, 1833. *State of the Surface.*

	Going from Barnet to Mims.								Going from Mims to Barnet.							
Distance.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.	Draught.
1	12	20	0	25	5	40	17		70	18	17	40	52	40	42	
2	28	15	0	18	5	40	30		55	17	30	20	42	37	30	
3	18	20	0	12	22	45	20		42	15	25	17	45	43	40	
4	17	20	0	28	14	50	15		40	20	30	27	45	40	32	
5	23	20	0	33	10	33	15		25	35	40	13	45	35	38	
6	14	25	2	24	6	43	15		25	35	30	15	56	35	30	
7	18	18	4	20	12	37	12		25	22	25	8	52	40	24	
8	29	20	2	20	12	28	16		23	22	32	10	53	38	22	
9	20	15	0	28	20	25	10		25	25	40	18	38	35	20	
10	20	30	4	20	32	20	12		25	22	30	20	35	40	15	
1 F.	19·9	20·3	1·2	22·8	13·8	36·1	16·2		35·5	23·1	29·9	18·8	46·3	38·3	29·3	
1	28	22	2	20	20	20	6		30	17	40	13	35	40	10	
2	25	25	8	17	20	16	20		35	25	42	22	30	40	5	
3	15	22	6	25	23	16	16		45	19	50	17	30	30	7	
4	22	19	0	15	27	19	20		35	32	45	30	38	30	28	
5	20	15	1	30	25	12	18		26	30	50	25	40	20	4	
6	20	22	8	38	25	20	13		40	30	35	15	45	25	17	
7	16	15	5	44	32	22	10		30	25	27	18	35	20	15	
8	12	12	10	30	30	15	8		30	27	20	14	38	27	15	
9	14	30	1	32	30	30	7		30	12	30	20	50	23	18	
10	0	20	4	22	38	30	0			10	35	12	50	20	23	
2 F.	17·2	20·2	4·5	27·3	27·0	20·0	11·8		30·1	22·7	37·4	18·6	39·1	27·5	14·2	

1	0	18	3	20	28	40			25	6	25	10	47	14		
2	0	20	17	10	30	35			35	4	28	12	52	25		
3	0	14	6	10	30	30			33	15	20	18	62	30		
4	7	11	4	8	21	25			30	3	25	20	45	22		
5	8	8	2	10	25	15			19	12	27	20	55	30		
6	9	5	0	15	25	13			28	10	40	13	55	40		
7	12	6	2	20	23	20			20	10	40	12	50	57		
8	13	4	5	8	24	30			24	8	45	22	33	62		
9	13	3	4	12	30	23			25	2	38	21	30	65		
10	0	7	14	2	30	25			30	12	30	22	45	45		
3 F.	6·2	9·6	5·7	11·0	26·6	25·6			26·9	8·2	31·8	17·0	47·4	39·0	21·75	
1	5	0	15	1	32	30			30	8	28	30	50	65		
2	0	1	17	13	35	28			30	12	30	30	42	65		
3	0	2	20	15	43	20			30	12	36	40	57	55		
4	0	0	22	6	51	30			45	10	47	35	65	40		
5	5	4	18	1	42	33			30	12	35	45	65	45		
6	5	0	30	14	48	36			55	20	40	40	34	35		
7	10	0	30	12	58	32			44	19	35	45	55	42		
8	10	0	20	12	50	28			38	12	33	58	42	38		
9	30	0	22	12	50	30			28	25	35	52	30	38		
10	13	0	20	12	50	30			25	20	43	60	43	45		
4 F.	7·8	0·7	21·4	9·8	45·9	29·7			35·5	15·0	36·2	43·5	48·3	46·8		
Mean of half Miles.	12·78	12·70	8·20	17·72	28·32	27·85	Mean of half Miles.		31·9	17·25	33·82	24·42	45·27	37·90		
Mean of Miles.	12·74		12·96		28·08		Mean of Miles.		24·57		29·12		41·58			

APPENDIX, No. II.

REPORT RESPECTING THE STREET PAVEMENTS, ETC. OF THE PARISH OF ST. GEORGE, HANOVER SQUARE.

1. PRESENT STATE.

In consequence of an application to me by the Pavement Committee of the inhabitants of this extensive parish, I examined the present state of the carriage-way and foot-path pavements, and endeavoured to learn the various circumstances connected therewith; I also made observations on the nature of the bottoming and shape of the stones.

The notorious imperfection of the carriage-way pavement having been the cause of this Report, it is needless to state, that the surface is generally very uneven, and not unfrequently sunk into holes, so as to render it not only incommodious but dangerous to horses and wheel carriages.

The causes of this imperfection are various, and of an extensive and serious nature.

The stones, though generally of a tolerably good quality, are so irregular in their shape, that even their surfaces do not fit; they almost universally leave wide joints, and, instead of these joints being dressed square down from the surface, that is, at right angles with the face, they more frequently come only in contact near the upper edges, and, by tapering downward, in a wedge-

like form, have their lower ends very narrow and irregular, leaving scarcely any flat base to bear weight.

This form also unavoidably leaves a great portion of space between the stones, which the workmen fill with loose mould or other soft matter of which the bed or subsoil is composed.

Another great defect is caused by inattention to selecting and arranging the sizes of stones; they are but too commonly so mixed, that large and small surfaces are placed alongside of each other, and, acting unequally in support of pressure, create a continual jolting in wheel carriages, which, adding percussion to weight, is a powerful and destructive agent.

I must add to these defects another of an equally serious nature, that is, the imperfection of the bed on which the stones are placed.

This bed has, hitherto, but too generally, been formed of very loose matter, easily convertible into mud; and this matter, instead of being compressed by artificial means, has unavoidably been loosened by a sharp-pointed instrument, to suit the irregular depth and narrow bottoms, and to fill the chasms between the joints of the paving-stones. From the width and irregularity of the joints, water easily sinks into, and converts the before-mentioned soft matter into mud, which, by the continual and violent action of carriage wheels, is worked upon the surface, and leaves the stones unsupported.

This operation must be very evident to every person who reflects upon the sudden accumulation of mud upon the surface of the carriage-way pavement after a light rain, &c., or a continuance of soft weather.

This accumulation of the before-mentioned defects

has, by degrees, arisen from carrying (perhaps, well intentioned) economy to much too great an extent, and which has been accomplished by the easiest of all means, that is, promoting too indiscriminate a competition, and thereby reducing the price so unreasonably low, as to oblige contractors to procure inferior materials, and prevent them from bestowing the necessary portion of labour upon dressing and setting them.

There is a defect also respecting the management of contracts, in so far as to proceed by the almost unavoidable, and hitherto unchecked, mode of performing the work by the square yard of certain depths (say nine inches). Now, as I understand that the paving-stones are usually purchased by the contractors by weight, the more imperfect the shape is, the more profit he will have upon the superficial yard, which unavoidably must consist of a very considerable portion of loamy material, which is soon converted into mud.

The mode of repairing the carriage-way, if I am rightly informed, is equally imperfect, and has, no doubt, in a considerable degree, also arisen from the gradual introduction of low prices for repairing with old stones, by the square yard, however frequently repeated. This naturally produces hasty and imperfect workmanship.

The streets have likewise, of late years, been greatly disturbed by the laying down and repairing of water-pipes, &c. &c.

2. PROPOSED MODES OF CONSTRUCTING MORE PERFECT STREET CARRIAGE-WAYS.

The foregoing statement renders it sufficiently evident that the carriage-way pavements of the metropolis

have reached a degree of imperfection which urgently demands reformation.

The defects having, however, been fairly stated, will assist us in discovering the best means of remedying them.

The result of the foregoing investigation undeniably is, that the surface of the carriage-ways of the streets is generally very uneven, not unfrequently dangerously rugged, and in constant need of repairs, and these combined circumstances have created strong prejudices against pavements.

Sundry modes have been proposed to get rid of these very general and well-founded complaints, which I shall now proceed to discuss.

One of the boldest of these projects has not only been proposed, but actually, to a certain extent, put in practice, by making a total change from a pavement surface to that of small broken stones. This radical change appearing to me to require all the judgment and experience which can be brought to bear upon it, I have not only exerted myself personally to acquire information, but have submitted the subject to repeated discussions at sittings of the Civil Engineers' Institution, when numerously attended by many of the ablest and most experienced engineers and surveyors, not only of the metropolis, but of various parts of the kingdom.

The result of these able and very candid discussions was, an unanimous resolution that whin or granite pavement, of proper form and depth, laid on a sound bottom, is preferable to any other mode for carriage-ways for the metropolis and other large cities, in order to form a body of strength adequate to bear the pressure and

shocks of innumerable carriages, many of them conveying several tons.

The chief objections advanced to small broken stone were as follows: — that they cannot resist the pressure caused by a very great intercourse, being liable to be thereby crushed and ground into dust, easily converted into mud; that this hasty and continual destruction and renewal would, in a great city, prove intolerably troublesome and expensive, while the dust in dry weather, and the mud in wet, would greatly incommode the intercourse in the streets; also private dwellings and public shops. Cases were instanced where absolute nuisances had been created by employing broken stones; and that it was well known that, in some large cities, the want of pavements led to accumulations of filth, very injurious to the health of the inhabitants. It was observed as a constant and abundant supply of broken stones would be required for repairs always hastily performed while the streets were empty, that receptacles, such as made in country roads, would not readily be found in London, where space is so valuable and so fully occupied. And it was further observed, that a surface of broken stones, frequently covered with dust and mud, was more injurious to the feet of horses than a properly constructed pavement, which is also much easier for their labour. And, lastly, that the expense of making and maintaining a street carriage-way with broken stones, including the constant labour and carting away scrapings to different depositaries, would be at least fifty per cent. more than by a proper pavement.

These observations corresponding with my own sentiments and experience, I am led to recommend pave-

ment in preference to broken stones for the carriage-way of the streets in St. George's parish.

3. OF THE BEST MODE OF CONSTRUCTING PAVEMENTS.

To obtain a smooth and durable pavement surface, the following essential matters must be attended to:—

1st, The bed, or bottoming, upon which the stones are to be placed.

2dly, The quality, size, and shape of the stones.

3dly, The mode of contract for constructing and keeping the pavement in a state of repair.

1. *Bottoming.*

After the space between the foot pavements has been brought into a form, consisting of a very slight curve in the cross section, every devisable means should be resorted to in order to render it compact and solid. Where practicable, it will be advisable to have wheel carriages to run for some time over it; or, occasionally, water; or to use the roller and stamper. These operations performed, it is necessary to cover the whole surface with a stratum, or layer, of some sort of substance, which will effectually cut off all connection between the subsoil and bottom of the paving-stones. This must itself be indissoluble in water, and prevent any of the substratum from rising in the shape of mud. Where stone can be cheaply procured, a bed of it, broken very small, would perfectly answer the purpose; and hence it has been observed, that the present broken stone experiments, in certain streets, will not be an entire loss, because they will, at all rates, constitute a good bed for a proper pavement. But, as

relates to the metropolis generally, I am persuaded that a bed of cleansed river ballast, about six inches in thickness upon an average, will be found to answer the purpose, and is to be obtained at a comparatively moderate expense.* This should also be rendered compact and solid; it might be travelled upon for some time without inconveniency, particularly in summer, being the season when paving is usually performed.

2. *Quality, Size, and Shape of Stones.*

The qualities of the granites hitherto used are not so materially different as to require much discussion; but as there are differences in stones from all quarters, the judgment of the surveyor, who has charge of the works, and is supposed qualified, ought to be constantly exercised to ensure a due fulfilment of the contract in regard to the materials. I have understood that, by former and recent experiments, the Guernsey stone is of great compactness and durability. This deserves attention and a fair and impartial trial. The only objection I foresee, is in its disposition to smoothness of surface.

With regard to size, it ought to be regulated, in some measure, by the nature and quantity of the intercourse through the several streets: they may be conveniently divided into three classes. For streets of the first class, or greatest thoroughfare, the stones should be not less than ten inches in depth, from eleven to thirteen inches in length, and from six to seven inches and a half in breadth on the face.

* On reconsidering this subject, I am of opinion that this quantity of ballast will not make a sufficiently strong bottoming, and that nothing short of twelve inches of broken stones, put on in layers of four inches each, and then completely consolidated by carriages passing over them, will answer the purpose. — T. TELFORD. *July* 18. 1833.

For the streets of the second class, the stones should not be less than nine inches in depth, from nine to twelve inches in length, and five to seven inches in breadth on the face.

For the streets of the third class, the stones to be not less than seven to eight inches in depth, from seven to eleven inches in length, and four and a half to six inches in breadth on the face. Crossings ten to twelve inches in length, seven to eight inches in breadth; the depth to be according to the classes.

All these stones to be worked flat on the face, and straight and square on all the sides, so as to joint close, and preserve the bed or base, as nearly as practicable, of an equal size to the face; and stones of equal breadth on the face, must be carefully placed adjacent to one another. The inferior streets, mews, and passages may be paved with the inferior stones from the other three classes, and those stones unfit for any pavement may be usefully employed by being broken small, as bottoming for the pavement of the first class of streets.

With regard to the shape of the stones, those modes I have hitherto been considering have been supposed rectangular, with joints made exactly to fit close to each other, and which, if perfectly executed, taking into consideration all the angles, the strongest possible, and also the most simple, whether we regard the preparation in quarrying and dressing, or the practical operations on the streets — right angles admitting of a variety of size, but always fitting, however applied, and, of course, under all these circumstances, the cheapest.

3. *Modes of Contract, &c.*

In constructing new pavements by the present practice, I have already stated, that it is the interest of the

contractor to work with stones of a defective shape. The making the superficial yard of face-work must, I conceive, still be continued as the rule; but, along with that, weight ought certainly to be combined, as a proof that the quantity of stone intended is really obtained; the shape of the stones must be accurately defined in a specification, and, *above all*, the surveyor or inspector must, by unremitting attention, see that every part of the contract is fully and faithfully performed. A further security for the perfection of the work would be obtained by making it a part of the agreement, that the contractor should keep the work in a perfect state of repair, at a given rate per yard, for a certain number of years; the necessary repairs to be from time to time pointed out by the surveyor, under the direction of the Committee.

In repairing the streets, as far as regards the stones now in use, although these stones are, undeniably, very imperfect, yet the quantity and value being so great, no project for rashly disposing of them is admissible; but a thorough improvement may be gradually accomplished in the following manner: —

The streets to be divided into three different classes. For the first, and most important, perhaps very few of the present stones are suitable; if there should be any, they may be reworked and replaced, and new stones of a proper shape (of course) provided for the rest of the street. The stones rejected from the first class should be carefully sorted and re-worked, for the repairs of such of the other classes as they are fit for, taking care that the stones, in all cases, are worked into proper forms, as regards the joints and bottoms; that the bottoming or bed has been formed of proper materials, not

convertible into mud by the water running down the joints, and that the stones, as to sizes, have been judiciously arranged.

It is now, I understand, the mode to repair by the yard superficial, in partial spaces pointed out by the surveyor, at a price per yard for each time. The contractor, therefore, has no inducement to have the operation performed in a complete and substantial manner; but, on the contrary, it is his interest to have a great quantity done by his workmen in a short time, because, the more frequently it fails, the more demand there is for his services. I do not by this insinuate unfair practices against any individual contractor, but the practice is undeniable.

To correct this apparent evil, it seems advisable to let a whole street, or certain number of streets, for a certain time, at a fixed price per yard; the necessary repairs to be pointed out by the surveyor, under the direction of the Committee.

From what I have here stated, it must be quite evident that, to acquire a necessary degree of perfection, the most unremitting and strict attention, on the part of the surveyor, is absolutely necessary; and that St. George's extensive parish is quite sufficient to employ the whole time of the most active and persevering man. He ought to have no other object, and his remuneration should be sufficient to attach him to his duty.

But even his most judicious and faithful exertions will be unavailing, unless a price is allowed equal to the fair value of the materials and workmanship, and a reasonable profit to the contractor, as I cannot help again stating, that the injudicious practice, which has of late years very generally prevailed, of reducing prices too low,

has led to the imperfect condition the street pavements are now in, and which, in works of this nature, is a very mistaken economy; for of all things, streets of great thoroughfare should not only be commodious, but very seldom interrupted.

A very perfectly constructed pavement might, I am convinced, combine smoothness, durability, and, in the course of a few years, true economy.

WATER-PIPES.

Formerly, when the main pipes consisted of wood, the rapid decay, and consequently frequent repairs, created a constant interference with, and very considerable injury to, the pavements; but since the introduction of iron pipes, these inconveniences have been greatly lessened, as experience has proved that very few repairs are found necessary.

The failures which now take place are almost wholly in the lead service-pipes from the subsidiary mains to the cisterns. There are two causes for this: the one is, by the subsoil of the street decomposing the pipe; the other, which is the more serious, arises from the effect of frost. It would, therefore, be very desirable if some other material could be used. I am convinced that a small iron pipe may be substituted with advantage. It would withstand the pressure, and might be laid with an inclination, so as to discharge its water either into the subsidiary main or the cistern, and thereby prevent its bursting by the effects of frost; and, in most cases, it would afford a supply of water to the houses even in severe frosts, because these subsidiary mains are generally laid sufficiently below the reach of frost.

SEWERS.

With regard to the openings which must unavoidably be made for common sewers, they so seldom occur, and may be so effectually secured, that their consequences do not require any serious notice.

STREET-WATERING.

The present mode of watering the streets from the plug-pipes, by throwing it about with scoops, is extremely injurious to the pavement joints. I therefore recommend that water-carts be substituted.

FOOT PAVEMENTS.

In the course of my examinations, I found that the foot pavements, though in some few instances requiring repairs, and even improvement, yet were, upon the whole, in a very fair state, and did not seem to require any separate discussion, or material change from the mode now practised.

I may merely observe, that, in future, it will be an improvement, that its surface may have a gentle declivity from the areas, or houses, towards the street; and that the new stones should, in the principal streets, be good Yorkshire pavement, not less than four inches in thickness.

GENERAL OBSERVATIONS.

From the foregoing discussion it is evident,—

1. That pavement is the most advisable mode of constructing street carriage-ways.

2. That the present street pavement is very imperfect, because the bottoming to receive it, being composed of a variety of loose materials, all easily convertible into mud, is very unfit for a foundation. And the irregular depth and shape of the stones placed upon such a bottom, with a generally small base, having only the support arising from the friction of the very trifling breadth which comes in contact near the upper edges (even when these parts of the joints are good), are easily pressed down into the aforesaid loose materials; and although ramming may assist the present mode, yet the irregularity of depth and base prevents it from constituting a perfect and durable pavement.

3. That it has become absolutely necessary to abandon the present imperfect mode of paving and repairing, and adopt a better one.

4. In order to commence the improvements (which I have stated may be gradually accomplished), I recommend that, in one of the streets of the first class, say about 100 yards, which are now in the most imperfect state, should be wholly taken up, and restored with new stones of proper dimensions and shape, placed upon well-prepared substantial bottoming, and the whole managed in the way described in the foregoing Report. —The stones taken up may be selected and re-dressed for the second class of streets.

For each operation, precise specifications, and drawings of the cross sections, should be prepared, and there should, in the commencement, be small specimens made of the new pavement, and also of the re-dressing, under the direction of a properly qualified person, who would enter with zeal into the spirit of the improvement. Upon these specifications and specimens, contracts might be entered into.

5. That, to ensure an effectual performance of what has been recommended, unremitting attention is absolutely required, and quite sufficient to occupy the whole time of an able, intelligent, experienced man.

I cannot close this Report without acknowledging the aid I have derived from the ready and full information afforded by the Agent of the Grand Junction Water Works Company in all that regards water-pipes, &c. &c.

(Signed) THOMAS TELFORD.

June, 1824.

APPENDIX, No. III.

OBSERVATIONS COMMUNICATED TO THE AUTHOR, ON MR. WALKER'S EVIDENCE BEFORE THE SELECT COMMITTEE OF THE HOUSE OF COMMONS, IN 1819.

WHEN Mr. Walker gave evidence before the Select Committee on roads, in 1819, he delivered a section of the Commercial Road paving, and also of the East India road, both of which were printed.

In the same evidence he stated that, for heavy traffic in each direction, it would be an improvement to form the paving on the sides of the road, and leave the middle for light carriages, by which the carmen, when on the footpaths or sides of the road, could be close to their horses, without interrupting or being in danger of accidents from light carriages, and the unpaved part, being in the middle or highest part of the road, would be more easily kept in repair. He delivered a section according to this plan.*

In 1820, two miles of the Middlesex and Essex road, from Whitechapel to Bow, were paved on the above plan. The specification for the contract was prepared by Mr. Walker, and the first part done under his direction. He appears to have taken great pains to ascertain by experiment the proportional durability of different stones; for which purpose he had pieces of equal weight and rubbing surface of Guernsey, Aberdeen, and Peterhead, placed loosely in a frame divided

* This plan of paving the sides of a road in place of paving the middle part, as recommended in this work, is no doubt a considerable improvement; but, both for conveniency and durability, the latter plan is decidedly preferable. — THE AUTHOR.

into squares, each stone occupying a square. The frame was moved back and forward for several days on a large block of stone with sand and water between, and the loss of weight noted each day. The Guernsey stood best, and the contract was made for it. This paving has now been in use thirteen years, with almost the heaviest traffic out of London on it, and, except the first year, when the contractor had to keep it up under his agreement, it has cost very little for repairs. It is now in excellent order, and the stones do not appear worn in the smallest degree. The paving is 9 feet wide, with a curb on each side, and the gravelled road between about 32 feet on the average; making the width of the road, exclusive of the footpaths, 50 feet.

Much praise for the excellent way in which this great road has been improved and kept, is due to the chairman of the trustees, John Henry Pelly, Esq. From being at one time the worst, it has, for twenty years, been the best, and is still one of the best roads out of London, and at the same time much the cheapest in point of toll. The tolls allowed by the Act are as under: those actually charged are 25 per cent lower.

	s.	*d.*
For a horse, &c. laden or unladen - -	0	1½
For a coach, &c. with five or more horses -	1	4
For ditto, with three or four horses - -	1	0
For ditto, with two horses - - -	0	6
For ditto, with one horse - - -	0	4½
For two-horse cart with wheels from six to nine inches - - - -	0	8
For waggon with two or more horses, and wheels less than six inches in breadth -	1	6
For one-horse cart - - - -	0	8
For dray with one or more horses - -	1	0

For waggon with one or more horses, and wheels six to nine inches broad -	1	0
For ditto, if wheels more than nine inches -	1	6
Oxen, &c. - - -	0	10
Calves, sheep, &c., per score - - -	0	5

A payment at Mile End gate clears from London to Brentwood (18 miles), and tolls are due only once a day.

The formation of the tramway on the Commercial Road gave Mr. Walker another opportunity of proving the absolute wear and comparative hardness of granites. The experiments were made on pieces of the tram-stone 18 inches wide and a foot deep, which, after being accurately weighed, were laid down in one of the toll-gateways where all the traffic from the East and West India Docks uniformly passed; on being taken up, the stones were again weighed, and the results were as under: —

First Series.

Laid, November, 1828. Lifted, March, 1829.	Time, Four Months.	
Description.	Loss of Depth.	
	Absolute.	Relative.
	Inch.	
Guernsey - -	·028	1·000
Budle * - - -	·029	1·025
Herm † - - -	·034	1·194
Blue Peterhead - -	·051	1·809
Red Aberdeen - -	·074	2·601
Blue Aberdeen - -	·086	3·039

* Budle is a whinstone from Northumberland; the others are all granites. † Herm is an island adjoining Guernsey.

Second Series.

Laid, March, 1830. Lifted, August, 1831.	Time, Seventeen Months.	
Description.	Loss of Depth.	
	Absolute.	Relative.
	Inch.	
Guernsey - - - - -	·060	1·000
Herm - - - -	·075	1·190
Budle -	·082	1·316
Blue Peterhead - -	·131	2·080
Heyton - - - -	·141	2·238
Red Aberdeen - - -	·159	2·524
Dartmoor - - - -	·207	3·285
Blue Aberdeen - -	·225	3·571

The second of the above series may be considered the more correct, from the longer duration of the experiment, and from the dressing of the stones of the different descriptions at the time of the first series not being quite equal.

APPENDIX, No. IV.

REPORT OF THE SELECT COMMITTEE APPOINTED TO ENQUIRE INTO THE AMOUNT OF ALL SUMS OF MONEY RECEIVED, EXPENDED, AND REPAID BY THE COMMISSIONERS FOR THE IMPROVEMENT OF THE HOLYHEAD AND LIVERPOOL ROADS.

May 30. 1830.

THE Committee have proceeded in making the enquiries referred to them, and find from the accounts which have been laid before them, that the Commissioners appointed by the act of the 55th Geo. 3. c. 152. for the improvement of the Holyhead Road, have received the sum of 759,718*l.* 6*s.* 11*d.*; that of this sum 338,518*l.* 14*s.* 1*d.* has been granted by Parliament, without any condition for repayment, for works in North Wales; that 394,114*l.* 6*s.* 6*d.* has been granted by Parliament, or advanced by the Exchequer Bill Loan Commissioners, by way of loan, towards the building of the Menai and Conway Bridges, the making of the new Road across the Island of Anglesey, and the improvement of the Road between London and Shrewsbury; and that repayments have been made to the amount of 103,633*l.* 2*s.* 2*d.* The details of the expenditure of the sum received by the Commissioners, of 759,710*l.* 6*s.* 11*d.*, are stated in an account in the Appendix.

In order to ascertain in what manner the Commissioners have applied the money entrusted to them, the Committee examined their engineer, Mr. Telford, who produced the statement which is here inserted, containing a short description of each work that has been executed by the Commissioners since they were appointed to superintend the improvemement of the Holyhead Road, in the year 1815, under the following heads: —

1. Roads made in North Wales on the London and Holyhead Mail line.
2. Roads made in North Wales on the Chester and Holyhead Mail line.
3. Embankments on the Stanley Sands and at Conway.
4. Bridges over the Menai Strait, and over the river Conway.
5. Roads made between London and North Wales on the London and Holyhead Mail line.
6. The Harbours of Holyhead and Howth.
7. The Road from Howth to Dublin.
8. The widening and deepening the Channel through the Swilly Rocks in the Menai Straits.

Statement of the Works performed between the Years 1815 and 1830.

HOLYHEAD ROAD. — NORTH WALES.

Holyhead to Chirk.

Between Holyhead Pier and Chirk Bridge is a distance of 83 miles 1,320 yards. The whole may be fairly considered a new road, as the short pieces of the old road were entirely re-made. The whole of the roadway

is constructed with a substantial rubble-stone pavement, carefully hand-set, and covered with a six-inch coating of properly broken stone. There are, in all cases where found necessary, breast and retaining walls of stone, with numerous side and cross drains, all constructed in the most perfect manner. The whole is protected with stone walls; those upon precipices built with lime mortar, most of the others pointed with it. There are several considerable bridges, also numerous cuttings and embankments, in that mountainous country; one, particularly, at the village of Chirk, is 50 feet in height. Four miles of branch roads have been made. The toll houses and gates are on a new construction, as are the milestones; and sufficient recessed depôts for stones have been made in every part of the road. An entirely new inn has been built in the middle of the island of Anglesey, upon the new line of road.

CHESTER LINE.

Tally Pont Hill.

From Tally Pont Bridge a new road has been made upon comparatively level ground, to avoid the inconveniently steep inclination of Tally Pont Hill, and to save distance, 1 mile 132 yards. This road is made with a pavement bottom, and a covering of hard field pebbles, properly broken.

Penman Mawr.

This improvement consists chiefly of rock cutting, in some parts 30 feet in height, with high breast and retaining walls, stone parapets laid in lime-mortar; the

roadway is formed of pavement bottoming and a coating of broken stone; so that this formerly frightful precipice is now a safe trotting road.—Distance improved, 1 mile 231 yards.

Penman Back.

Between Penman Mawr and the town of Conway, excepting a short distance, a new road has been made to avoid Sychnant Hill, over which the mail road formerly passed, by dangerous inclinations, to upwards of 540 feet above the level of the sea. The new road is nearly level, having no inclination more than one in twenty-five, and that only for a short distance of about 100 yards; the rock cutting required in some instances, in the face of a precipice, 100 feet in height. The roadway is, in all respects, similar to that at Penman Mawr, as to breast and retaining walls, parapets, &c.—Distance improved, 4 miles 1408 yards.

Rhyalt Hill.

Up a valley between St. Asaph and Holywell, a road has been made to ease the steep and long-continued ascent of Rhyalt Hill, which, in some cases, was one in seven. The new roadway is made with bottom paving and broken limestone, with very good side and cross drains.—2 miles 1166 yards.

EMBANKMENTS IN NORTH WALES.

Stanley Sands.

Near Holyhead there is an inlet of the sea, known by the name of the Stanley Sands: over this estuary an embankment, 1144 yards in length, has been made; the

height above the undisturbed surface of the sands, in the middle, is 29 feet: the breadth at the top, including the parapet walls and outer facing, is 34 feet; the slopes on each side are at the rate of three to one, and these slopes are faced with rubble stone, two feet in thickness; on each side of the road there is a parapet four feet in height, coped with cut stone. The roadway is 24 feet in width; it has a paved bottom and a coating of broken stone. In order to admit the tide to flow into the space on the west side of the embankment, there is a bridge built upon the only piece of natural rock found in that part of the estuary. This work was executed in two years; 156,271 cubic yards of earth, and 25,754 cubic yards of rubble stone, were deposited in forming it: it has been completed seven years, and is now in a perfect state.

Conway Embankment.

The eastern approach to Conway Bridge is formed by an embankment upon the sands, over which the tide usually flowed, and rendered it a very difficult and dangerous passage. The distance from the eastern shore to the island is 672 yards; the height of the embankment, on account of the sand being swept away by the violence of the tides during the execution of the work, is 54 feet; its breadth at the base is 300 feet, and 30 feet at the roadway: the side slopes are faced with rubble stone.—261,381 cubic yards of earth, and 51,066 cubic yards of rubble stone, were employed in forming it. The whole has been finished three years, and is now in a perfect state.

BRIDGES IN NORTH WALES.

Besides several stone bridges, three of a novel description were required:—

Menai Bridge.

Over the Menai Strait, which separates the island of Anglesey from Carnarvonshire, in order to supersede an inconvenient ferry, it was found, after many years' investigation and discussion, that, in a navigable and rapid tideway, a bridge upon the principle of suspension was the most practicable and economical; a bridge of that description, therefore, was begun in 1818, and successfully completed and opened on the 30th of January, 1826. This structure being of very unprecedented novelty and magnitude, considerable apprehensions were entertained concerning its stability; the engineer, therefore, by the advice of his friend, the President of the Royal Society (one of the Commissioners), considerably increased the height of the piers, and the dimensions of the masonry and ironwork, beyond the original design, and this unavoidably led to corresponding increase of expense; but as all the works were paid for at the prices previously fixed in making the first estimate, and as the quantities have been ascertained by measurements and weights correctly made by the resident engineer, the public has only paid for what was actually found in the work, and the edifice is thereby rendered more substantial.

The contractor for the iron works having made a claim on the Commissioners for alleged loss sustained by him in consequence of the unprecedented rise in the price of iron, the Commissioners felt themselves justified, on

enquiry, in representing to the Treasury that the difference between the price paid by him for 2000 tons of iron, employed on this and the Conway bridges, and the price at which the contract had been made, exceeded 4500*l.*; but this claim was not admitted.

The distance between the points of suspension, for the middle opening, is 580 feet, and between the pyramids and toll-houses about half as much, to which is to be added what passes down the galleries to the places of fixture in the rocks, making the whole length of each main chain 1750 feet, or one third of a mile.

The height from low water to the top of the saddles on the pyramids is 181 feet; and between the saddles and the roadway, 60 feet.

The breadth of the platform is 30 feet, and consists of two driving ways and a footpath between them.

There are four stone arches on the Anglesey side, and three on the Carnarvonshire side, each 52 feet 6 inches span.

This bridge has been in constant use four years, has required no repair but painting, and is now in a perfect state.

Conway Bridge.

At the town of Conway, between the before-mentioned island and the rocks in front of the old castle, there is a space through which the tide flows with very considerable velocity: over this space there has been made a bridge on the same principle as the Menai; it is 327 feet between the points of suspension; in this there is only a single roadway. The main chains are fixed in rocks at each extremity; the western approach is by a gateway formed in the old town wall, and by an embrasured

terrace around the basement of one of the towers; the masonry of the supporting pyramids, and also the toll-house, is made to correspond with the old castle.

Waterloo Bridge.

Where the Shrewsbury road crosses the Conway river, above Llanrwst, it was necessary to build a new bridge of one arch, 105 feet span; and building stone of proper dimensions and quality not being to be had at any moderate expense, this bridge is built of cast iron. The main ribs consist of the following words in roman capitals:—"This bridge was constructed in the same year the battle of Waterloo was fought;"—and having the national emblems, the rose, thistle, and shamrock, in the angles, it becomes a public and lasting testimonial of the action which so splendidly terminated the war.

THE ROAD BETWEEN LONDON AND NORTH WALES.

Highgate Archway Road.

This road being upon a clay soil with springs of water, originally very imperfectly made, never properly repaired, and at last totally neglected, it became absolutely necessary to thoroughly re-make the whole upon proper principles.

The roadway bottom was, therefore, completely opened, and numerous side and cross drains constructed, so as to carry off the water. Next, in order effectually to prevent the water, or even the damp from the clay, affecting the roadway, a bed of concrete, composed of Parker's cement and washed gravel, six inches in thickness, was laid over it, which, at the same time, formed a

substantial bottoming for the road metalling: upon the bed thus prepared, there has been laid a coating of broken Guernsey granite.

There has been a regular footpath formed along each side of the road: the slopes of the deep cutting on each side of the archway, which were cracking and slipping down, have been dressed and sown with grass seeds. The whole remaining now in a perfect state after a trying winter, is an instance that even a seemingly desperate case may, by proper exertions and skill, be effectually remedied; and also proves of what importance it is to have a road very perfectly made at first.—Distance improved, 1 mile 892 yards.

Barnet and South Mims Road.

Between the town of Barnet and the village of South Mims, an entirely new road has been made, with two bridges and a regular footpath; proper recesses have been made for containing repair stones, clear of the roadway; the toll-house and milestones are of the same plan as those in North Wales.—Length, 3 miles 352 yards.

St. Albans Road.

A new road has been made from the Red Lion Inn, in the town of St. Albans, across the river Vere to Pond Yards, with considerable cuttings and embankings, and a bridge over the river.—Length, 2 miles.

Hockliffe Hills.

An extensive improvement has been made at Hockliffe Hills, consisting wholly of deep cuttings and embankings; the roadway is formed with rubble stone pavement

bottoming, covered with broken pebbles.—Length, 1 mile 1672 yards.

Sandhouse Hills.

This improvement consists wholly of cuttings and embankings; the roadway is constructed as the last mentioned.—Length, 1320 yards.

Brickhill.

There is a new piece of road at Brickhill, chiefly cutting and embanking; the roadway same as last. — Length, 880 yards.

Fenny Stratford.

At this village, the hollow west of the bridge has been raised by lowering the hill in the street, the roadway has been widened, several houses have been removed, and others underbuilt; fence walls, railings, and stairs have been constructed. — Length, 451 yards.

Old Stratford.

At Old Stratford village the road has been raised, widened, and made with paved bottom, and coated with Mount Sorrel stone. — Length, 370 yards.

Gullet Hills.

This improvement consists of cuttings and embankings; the roadway is constructed with a paved bottom, the workable part covered with broken limestone. — Length, 1540 yards.

Cuttle Mill.

In this valley there is an embankment 44 feet in

height, a cutting 15 feet in depth, a new bridge, and a pavement roadway.—Length, 1452 yards. There is an additional piece of repaired road:—Length, 400 yards.

Towcester.

Some banking and cutting, and a new pavement roadway.—Length, 247 yards.

Between Towcester and Foster's Booth.

Six hills cut down and hollows filled, and a new pavement roadway made over them.—Length, 1178 yards.

Stowe Hills.

Over these hills there are several very considerable cuttings and embankings; the roadway is made with a rubble-stone pavement, having a coating of broken Hartshill stone as road metal.—Length, 1 mile 1120 yards.

Braunston Hill.

This improvement consists chiefly of cutting and embanking; the roadway is constructed, as the last-mentioned, with Harsthill stone.—Length, 1 mile 306 yards.

East of Coventry.

The new road east of Coventry has considerable cuttings and embanking; the roadway is similar to Stowe Hills, with a paved bottom and Hartshill top metal; there is a considerable new bridge, with recesses for stone depôts.—Length, 1 mile 272 yards.

West of Coventry.

The new road between the city of Coventry and the village of Allesley is the same in all respects as the last mentioned, as to roadway, bridges, and depôts; but, in addition, there are two new toll-houses and gates. — Length, 2 miles 240 yards.

Pickford Brook to Meriden.

At Meriden a new road has been made by very considerable rock cutting and embanking; the roadway is paved with hard sandstones, and coated with hard Warwickshire pebbles properly broken. From Meriden Hill to Pickford Brook Hill the road has been put into a proper form, and coated with six inches of broken pebbles. A new road has been made down Pickford Brook Hill, with a paved bottoming, coated with broken pebbles. This road from Meriden to Pickford Brook has scarcely needed any repairs during the last six years. — Length, 2 miles 88 yards.

Wednesbury.

Here a new road has been made across collieries, &c. below the town, in order to avoid a steep hill, and save a considerable distance. The bottom of the roadway is paved and coated with broken stones. — Length, 1 mile 704 yards.

Bilstone.

This new improvement saves passing along a very awkward street, and is only about half the distance; it is constructed in the same manner as the last mentioned. — Length, 1150 yards.

Wolverhampton.

The Wolverhampton improvement has been carried partly over a level field, and partly through old houses in the town; the roadway bottom is made with large cinders, and coated with Rowley rag and Pouck Hill stone. — Length, 1199 yards.

Summerhouse Hill.

The first contract proceeded from the public house downwards to near Bonigale public house; it is all cutting and embanking; the bottom of the roadway is paved, and the top covered with broken pebbles. — Length, 858 yards.

The second contract consisted in lowering the hill above the public-house, and embanking the hollow east of the hill; the roadway made as the last. —Length, 1584 yards.

Cosford Brook.

In this formerly steep and dangerous pass there is very considerable cutting in rock, and embanking; a bridge has been widened and raised; the roadway made as at Summerhouse. — Length, 700 yards.

Town of Shiffnal.

This improvement is partly over fields on the west of the town, and partly through some houses adjoining the market-place, and across a brook, where a new bridge has been built; the bottom of the roadway is paved, the top is of broken pebbles. — Length, 456 yards.

Knowles Bank.

Consists wholly of cutting and embanking, and making the roadway same as last. — Length, 957 yards.

Llewellyn.

Here a new road, from the last-mentioned improvement, has been made to Prior's Leigh, in the same way as that at Shiffnal. — Length, 1689 yards.

Prior's Leigh.

At Prior's Leigh there is much cutting and embanking; the roadway has a paved bottom and a coating of broken whinstone; the whole is fenced by stone walls. — Length, 1724 yards.

Ketley Works.

At Ketley Iron-works an improvement has been made, consisting of cuttings, and an embankment 23 feet in height, also an arched roadway under it; the roadway has a paved bottom, with a covering of broken stone; the fences are of cinders from the iron-works. — Length, 816 yards.

Gobowen to Chirk Bridge.

From the village of Gobowen to Chirk Bridge there is an entirely new road; the bottom is paved and covered with a coating of broken stone. There is one bridge over the canal. — Length, 2 miles 1452 yards.

It is fit to observe, before I conclude this description of the roads made in England, that the work has been chiefly confined to cutting and lowering hills, and form-

ing long and high embankments, so that the greater part of the expense has been incurred in moving earth.

HARBOURS.

Holyhead Harbour.

The money granted for this harbour, since it was put under the Holyhead Road Commissioners in 1823, has been expended in giving additional security to the great pier, the lighthouse and roadway; in deepening the harbour, and laying down moorings for above fifty sail of vessels: this last work relieves the space allotted to the post-office packets. A large anchor has also been laid down at the north pier head, for their security in stormy weather.

The graving-dock, which was in hand in 1823, has been completed; proper gates have been put up, and also a Boulton and Watt's engine; a carpenter's shop, smithy, and storehouse have been built; also a gatehouse and a boundary wall, enclosing the dockyard. A road has been made from the town of Holyhead, communicating with the dock along the south side of the harbour.

About two thirds of the south protecting pier have been built, and backed with rubble stone.

On the north side of the harbour, at the root of the great pier, a lock-house has been built; also a harbour-master's office, with a turret clock-house and clock, and a custom-house.

Lamp-posts and lamps, posts and chains, have been put up, and good footpaths have been formed along each side of a new-made road between the landing pier and the principal inn; and a coach-house and workshop, for

the use of the mail coaches, have been built adjoining the inn.

A considerable quantity of rubbish has been removed from the harbour by the diving bell, and the landing place at the pier has been rendered more commodious.

Howth Harbour.

The money granted for Howth harbour, since 1823, has been applied as follows:—

In renewing the railroad between the harbour and the quarries at Kilrock, providing a quantity of suitable stones, applying a part of them in strengthening the glacis at the back of the eastern pier and that side of the harbour, and having a quantity in readiness in case of injury from storms.

The roadways upon and adjacent to the piers have been put into a perfect state, and the inner edges of the quays have, in part, been secured by posts and chains.

The entrance to the harbour and the packet births have been deepened by taking up 5963 tons of rock by means of diving bells, and 19,967 tons of sand and mud by dredging machines; thereby affording 11 feet of water at low water of ordinary spring tides, where there was only eight feet before.

HOWTH ROAD.

Between Howth harbour and Dublin, a distance of eight miles, the road (formerly very imperfect) has been wholly re-made, and rendered in all respects similar to the Holyhead road; it is now in a perfect state, having a proper cross section, and being smooth and substantial. A considerable sea-wall has been built to protect

the road. It is now referred to as a model for other roads in the vicinity of Dublin.

SWILLY ROCKS.

In the Menai Strait, immediately to the westward of the site of the new bridge, the navigation was rendered inconvenient by the strong currents acting upon a parcel of rocks known by the name of the Swillys; and it was stated by nautical men, that, unless these were so far removed as to lessen these currents, the difficulties and risk would be increased by the new bridge.

Considerable exertions were therefore made, whereby not only have the several rocks complained of been sufficiently cut away, but a projecting point of land has been taken off; and, upon the whole, it is acknowledged that the navigation generally is much improved, and that no inconvenience is experienced from the erection of the bridge.

THOMAS TELFORD.

The Committee having called for an account of the several contracts which have been entered into by the Commissioners, find that one hundred and fifty-one contracts have been made for carrying into execution the several works already described. They also find that all the works contracted for have been executed for the stipulated sums, except in one instance, wherein an exceeding took place of 76*l.* 15*s.*

The Committee beg to refer to the evidence of Mr. Telford for an explanation of the mode by which the contracts have been managed, and to the evidence of

Mr. Milne for an explanation of the manner in which payments have been made to the contractors.

An account, which is given in the Appendix, contains the salaries and other charges paid under the direction of the Commissioners.

It appears that the total sum paid for works amounts to 697,637*l.* 10*s.* 6*d.*; and that the sum paid in fifteen years for charges of management amounts to 28,460*l.* 4*s.* 1*d.* This charge is something under four and a quarter per cent. on the expenditure. The sum of 4583*l.* 4*s.* 7*d.* has been paid for parliamentary fees in passing Acts, and for exchequer fees; and 2821*l.* 8*s.* 5*d.* for solicitors' bills for passing Acts of Parliament, and other general business.

The Committee find that the Commissioners, immediately upon the harbours of Holyhead and Howth being placed under their management, in the year 1823, reduced the amount of the salaries to officers 611*l.* 7*s.* 6*d.* a year, and that they have subsequently dispensed with the services of two assistant engineers: the number now employed is, one between London and North Wales, another in North Wales, who has the care of the suspension bridges and the harbour of Holyhead, and superintends all the road business of the Commissioners; and a third, who has the care of the harbour at Howth, and of the road from Howth to Dublin.

In the Appendix an account is given of the additional Tolls levied for the repayment of loans advanced for the improvement of the road between London and North Wales; the amount of the loans advanced by the Commissioners for the loan of exchequer bills on the credit of these tolls is 44,000*l.*, and the amount of the repayments which have been made is 32,781*l.*

Sir Henry Parnell and Mr. Telford have been examined on the present state of the roads, embankments, bridges, and harbours; and the Committee have to represent, that these works are in a perfect condition, and likely to continue so, in consequence of the complete and durable manner in which they have been constructed.

The Committee beg to refer to the letters, which they have inserted in the Appendix, of several coach proprietors and coachmen, as showing the benefits derived from one of the last pieces of road-work which have been executed by the Commissioners.*

The Committee have to observe, that, although the expenditure on these works, in the course of the last fifteen years, has been considerable, great advantages have been derived to the public from the improved state of the road, and the more rapid and regular communication between England and Ireland; a large saving has been effected by several measures of public economy which have been adopted in consequence of the improvement in the communication between London and Dublin: such, for instance, as the abolition of the separate revenue boards, and the transferring of the chief management of all the revenue affairs of Ireland to London. An annual sum of 12,000*l.* has also been saved, which was expended, before the roads were improved, in maintaining an express establishment for carrying the correspondence of government between London and Dublin; and the postage revenue on letters passing between Dublin and England has considerably increased.

* This alludes to the Archway road: a few of the letters referred to, are given in a previous chapter.

As all the works have been executed by contract and competition, and as it appears that several of the contractors have failed, the Committee consider this a proof that the prices at which the contracts were made could not have been beyond what were fair and sufficient.

The Committee, on the whole, feel themselves justified in saying, from their enquiries into the proceedings of the Commissioners, that the works executed by them afford an example of road-making on perfect principles, and with complete success; and, in making this Report to the House, they cannot conclude without stating their high sense of the public and permanent benefit which has resulted from the unexampled exertions of Sir Henry Parnell, in discharging his duties as a commissioner of the Holyhead road, and from the great skill displayed by Mr. Telford in overcoming the seemingly insuperable difficulty of erecting a bridge over the Menai Strait, and also in every other work which he has executed.

APPENDIX, No. V.

The following are the principal Clauses of the Act, 50 Geo. III. c. 120., for the management of the common Highways in the County of Forfar.

III. And be it enacted, that the said county be divided into four districts, as follows, viz: — the first district comprehending the parishes of Dundee, Strathmartin, Monikie, Auchterhouse, Liff and Benvie, Monifieth, Mains, Murroes, Tealing, Lundie, Kettins, and Foulis, or such parts of them as are in the county of Forfar; the place of meeting being Dundee: the second district comprehending the parishes of Forfar, Kerriemuir, Inverarity, Glammiss, Kennettles, Cortachie and Clova, Dunichen, Rescobie, Lintrathen, Coupar, Airley, Kingoldrum, Eassi and Navy, Ruthven, Glenisla, Newtyle, or such parts of them as are in the county of Forfar; the place of meeting being Forfar: the third district comprehending the parishes of Brechin, Montrose, Marytown, Farnwell and Kinnaird, Fearn, Menmuir, Lethnot, Strackathro, Edzell, Lochlee, Dun, Caroldston, Craig, Logie and Pert, Oathlaw, Aberlemno, Tannadice; the place of meeting being Brechin: the fourth district comprehending the parishes of Arbroath, Carmylie, Barrie, Lunan, Panbride, Kirkden, Guthrie,

Saint Vigeans, Kinnel, Inverkeiller, Arberlot; the place of meeting being Arbroath.

V. And be it further enacted, that every person who is at present, or hereafter shall be in his own right, or in the right of his wife, in the actual possession and enjoyment as proprietor or life-renter of the full property or dominium utile of lands in the county of Forfar, valued in the cess books of the said county, to the extent of 100*l.* Scots, and all and every the eldest sons of such persons, and one guardian or trustee of minors possessed of lands to that extent, and all persons in the commission of the peace of the said county, who shall have qualified accordingly, the provost and the two eldest baillies in each of the five royal burghs within the county for the time being, and the sheriff depute and sheriff substitute of the said county for the time being, shall be, and they are hereby nominated and appointed trustees for the surveying, ordering, repairing, and keeping in repair the roads and highways, and for building new bridges, where the same shall be found necessary, in the said county: provided always, that every trustee qualified to act as being a proprietor or life-renter of lands within the said county, shall and may execute the powers hereby granted in any of the districts herein-before described, wherein his principal residence shall be, although such trustee shall not be possessed of any lands or heritages within such district.

VII. And be it enacted, that from and after the first day of July, 1810, all occupiers of lands, whether proprietors or tenants, shall be liable to pay yearly an assessment or conversion money, in lieu of statute labour, for the lands occupied by them respectively, according as the said lands stand valued in the cess books of the

county, at a rate not exceeding the sum of 2*l*. 8*s*. sterling, for each 100*l*. Scots of such valued rent: provided always, that if the majority of trustees of any particular district or districts within the county, at a regular meeting or meetings, held, and previously intimated for the purpose, shall desire the maximum to be raised to 3*l*. sterling for each 100*l*. Scots of valued rent, either for the whole district, or any particular parish or parishes therein, the trustees of such district or districts may apply to the annual general meeting of the county; and in that case, such annual general meeting shall have power, and is hereby authorized to assess the district or districts so applying, or any particular parish or parishes therein, in any sum not exceeding 3*l*. sterling, for and upon each 100*l*. Scots of valued rent; and that for any year in which the application is made, and for any year or years thereafter, when similar applications are repeated: provided always, that in the case of a partial assessment upon any particular parish or parishes, a majority in number of heritors, qualified to act as trustees in such parish or parishes, shall concur in the application for increasing the rate of assessment as aforesaid; and all occupiers of burgh roods, or lands lying in the territory of royal burghs, whether proprietors or tenants, shall pay, as an assessment or conversion for statute labour, a sum not exceeding 6*d*. sterling, per annum, for each 1*l*. sterling of yearly real rent, payable for burgh land so occupied by them, which shall be diminished in the same proportion that the aforesaid assessment or conversion of lands in the parish shall be diminished, as herein-after mentioned, below the 2*l*. 8*s*. sterling, for each 100*l*. Scots of valued rent; and where any person or persons occupy any profitable land, on which a horse or horses,

ox or oxen, are employed or used for its working or improvement, which lands are not valued in the cess books of the county, the said person or persons shall pay, as an assessment or conversion money for statute labour, a sum not exceeding 3*s.* sterling for each horse, and not exceeding 1*s.* 6*d.* sterling for each ox; all those keeping coaches or chaises for private use, or to be let to hire, shall pay yearly, as an assessment or conversion money for statute labour, 12*s.* sterling for each coach or chaise, having four wheels; and 6*s.* sterling for each chaise, chair, or gig, having two wheels, whether for private use or for hire; and all innkeepers, carters, carriers, and other persons keeping horses for hire, or for carrying goods in their carts for hire, shall pay, as an assessment or conversion money for statute labour, for such horses, a sum not exceeding 4*s.* 6*d.* sterling, yearly, for each horse so kept for hire; and all householders or inhabitants of royal burghs and villages, that now are or hereafter may be erected, and the occupier or occupiers of any house within the said county, not having any cultivated or profitable lands, except a garden annexed thereto, shall, in place of their statute labour, pay yearly an assessment or conversion money, not exceeding 1*s.* sterling, for every dwelling house occupied by them, whereof the yearly rent is 1*l.* 10*s.* and under 3*l.* sterling; an assessment or conversion not exceeding 1*s.* 6*d.* sterling, for every dwelling house occupied by them, whereof the yearly rent is 3*l.* and under 5*l.* sterling; and for every dwelling house occupied by them, whereof the yearly rent is 5*l.* or upwards, two and a half per centum per annum, for and upon the amount of yearly rent; and all persons who keep carriage or saddle horses, shall pay yearly an assessment not exceed-

ing 6*s.* sterling for each horse (exclusive of the above rate for coaches, chaises, chairs, or gigs let for hire); which said assessments or conversions shall be diminished in the same proportion that the aforesaid assessment of 2*l.* 8*s.* sterling on each 100*l.* Scots of valued rent, shall be diminished in each parish, as herein-after mentioned, declaring that all the aforesaid assessments shall be made and payable in each year, during the existence of this act.

XIII. And be it enacted, that the said trustees, or any seven or more of them, shall, in order to carry this act into execution, meet at Forfar, upon the second Monday after the passing of this act, and shall afterwards meet at the same place upon the first Tuesday after the 29th day of September, 1810, and thereafter, yearly, upon the same day and at the same place that the commissioners of supply shall be directed by the land tax act of the year then current to assemble; and upon the first Tuesday after the 29th day of September yearly; and the said trustees shall, at the said general meetings, have power to adjourn, from time to time, as they see cause, and to name a preses or chairman of their meeting, and a clerk, during pleasure, who shall attend the meetings of the said trustees, and shall enter their whole proceedings regularly in a book to be kept for that purpose; and likewise shall, as often as required by any person or persons having an interest in the same, make and give out copies or extracts of the orders or proceedings of the trustees, within three days after such requisition (at such certain moderate fees for the same as shall be fixed by the said trustees in a general meeting assembled); and such copies or extracts shall contain the warrant for putting these orders into execu-

tion: provided always, that no order or determination of the said trustees, which shall have been made at any annual general meeting, shall be annulled, varied, or altered but at some subsequent annual general meeting, nor unless notice thereof shall have been given by advertisement, to be twice published in one of the Edinburgh newspapers, thirty days before such subsequent meeting.

XVII. And be it enacted, that the trustees, or any three or more of them in the said districts, at their first meeting, or any adjourned meeting, shall be empowered to name a preses or chairman of their meeting, and a clerk during pleasure; and that they shall superintend and have the direction and cognizance of the several roads and bridges within their respective districts; and shall have power to appoint the order in which the same shall be made and repaired, and to appropriate the monies and services to be exacted and raised by virtue of this act from each district, but in such a manner that the money or services exacted from each parish shall be laid out upon the roads of that parish only, unless two thirds of the trustees having property in any parish shall agree that the whole or any part of such monies or services should be applied to other roads; and provided that the money or services assessed upon or exacted in country parishes shall be wholly expended or applied on roads not turnpike, excepting the money levied in burgh and upon burgh roods, which may be laid out as herein-after provided, and also excepting the share of each parish in the expence of clerks, collectors, and surveyors, overseers, and other officers, which proportion shall be regulated by the district meetings; and the said trustees, at the said district meetings, are hereby

empowered to appoint surveyors and overseers for the repair of the roads within their respective districts, and to allow them suitable salaries, and to remove or dismiss them, and appoint others, as they shall find necessary; and the said surveyors and overseers may, by a justice of the peace of the bounds, be made constables, for the special purpose of acting as constables in the business of the highways and roads, and for that purpose only.

XXI. And be it further enacted, that the said trustees in each district shall hold a meeting annually, some time before the general meeting appointed to be held on the same day that the commissioners of supply shall be directed by the land tax act of the year then current to assemble, and shall make up a particular state of the roads and bridges within their respective districts, and estimates of the sums necessary for the repair of them for the then current year; and they shall likewise make out an account of the application of the assessment, composition money, and services of the preceding year; which state, estimate, and account shall be laid before the general meeting, and engrossed in the book of their proceedings: and, according to the said state and estimate, if it be approved of by them, the said general meeting shall fix the rate of assessment and proportion of composition money corresponding thereto, to be levied in each district, and in each parish in that district, for the then current year; and if the trustees of any district neglect or omit to prepare such state and estimate, and to lay it before the said general meeting, then the trustees in said general meeting assembled are hereby empowered and required to assess the said district in the maximum assessment, and to levy the highest proportion

of composition money for the then current year, and to appoint a committee of their own number to apply the money to the repairs of the said roads and bridges within the respective parishes where it is levied: and further, in case of such neglect, omission, or failure, the clerk of the general meeting shall, and he is hereby required to apply to the sheriff depute, or his substitute, of the county, who shall grant warrant for summoning the clerk of the district so failing, or other person or persons to whom the said failure or neglect is imputed, and, on proof thereof, shall fine him and them in a sum not exceeding 10*l.* sterling, to be paid to the said trustees, and to be applied by them to the repair of the said roads; and the prosecutor shall yearly report to the first adjourned general meeting after the 30th day of April the issue of such prosecutions.

XXIV. And be it further enacted, that if any district shall neglect or omit to lay before said general meeting an account of the application of the assessment and composition money of the preceding year within that district, in that case the said general meeting are hereby impowered and required to appoint a committee of their own number, to inquire into the cause of the said neglect, and to report to them at their next general meeting, or adjourned general meeting; and if it shall appear that the trustees of the said district have neglected to meet, or to levy the assessment for the preceding year, or shall have neglected to lay out said money upon the repairs of the roads and bridges after having levied it, in that case the said general meeting are hereby impowered and required to appoint a collector or collectors, and to levy the said assessment and composition money, and likewise to name a committee

of three or more of their own number, who shall be vested with all the powers given by this act to the district meetings, for the application of said assessment or composition money towards the repairs of the roads and bridges within the respective parishes where it is levied.

XXXIII. And be it further enacted, that the said trustees, in their general or district meeting, or a quorum of them, which is hereby declared to be seven at a general meeting, and three at a district meeting, shall, and they are hereby authorized to cause the highways or roads, bridges, and ferries, within the said county, to be amended, widened, and repaired in such manner as they shall think proper; and to settle the direction of any of the said roads; and to make, or cause to be made, causeways; and to cut or make drains, ditches, or trenches through any grounds lying contiguous to the said roads; and to make passage for the water, where it shall be found necessary, from such ditches or trenches through the ground of any adjacent proprietor; and also to keep clear such drains, ditches, passages, or outlets; and the workmen, authorized by them, may go upon the said lands for that purpose: provided always, that reasonable satisfaction be made to the owner or occupier of such land for the damage to be done thereby: and if the said owner or occupier shall not be satisfied with the allowance offered by the said trustees, he shall be at liberty to apply to the quarter sessions, who shall have power finally to settle the same.

XXXIV. And be it further enacted, that the said trustees, in their general or district meeting, or a quorum of them, shall, and are hereby authorized and empowered to cause new arches and bridges of stone, brick, or timber, to be made and erected upon the said roads;

and any old bridges which may become useless or unnecessary, by changing the course of the roads, or otherwise, to be pulled down, and the materials thereof to be sold or applied in building new arches, or for repairing the said highways or roads, as they shall see proper; and also to cause such parts of the said roads as are not of a sufficient breadth to be widened, and made of such breadth as they shall think proper, not exceeding forty feet, free of ditches: and also to cause the course of such part or parts of the said roads, as they shall think proper, to be changed or altered, for shortening the same, or for making them more accessible; and to carry the same through and over such grounds and fences, as to the said trustees may appear most proper, accessible, and convenient; and along or through any bye or other roads, which may be more convenient than the old course of any of the said roads; in which case the said bye road, as far as it is joined by any of the said roads, shall be considered as part of them; and for these purposes, if necessary, to cause remove fences, or pull down any houses, the side walls of which, are not more than twelve feet high, upon giving the occupiers of said houses legal intimation of removal; and the road so altered shall, from thenceforth, be deemed and taken to be a public highway; and shall be repaired and amended, and kept in repair, in the same manner as the said highways directed to be repaired by this present act.

XXXVIII. And be it further enacted, that in altering or widening the said roads, or in making such new course of the roads, or such roads of communication, or in pulling down any house or houses, or part or parts of any house or houses, by the authority of this act, in

case no agreement shall have been made with the owner or owners, occupier or occupiers of the land where the roads are to be so altered or widened, or such new course of roads, or roads of communication made, or whose fences are to be altered or removed, or with the owner or owners, occupier or occupiers of any house or houses, or part or parts of any house or houses which are to be pulled down, application shall be made to the sheriff depute or his substitute, to summon a jury, in order to value the ground necessary to be taken and used, or houses necessary to be pulled down; and the loss or damage ensuing from the altering or removing of fences; and the said sheriff depute, or his substitute, is hereby empowered and required, upon such applications, to order intimation thereof to be made to the owner or owners, occupier or occupiers of such ground or houses; and afterwards to issue a summons, in the usual manner, for calling together and impannelling a jury, to consist of fifteen persons in number, to examine into, and after such examination, to return a verdict upon oath, as to the value of such land, fences, or houses; and thereupon the sheriff depute or his substitute, is hereby required to adjudge payment of the value and amount of the loss and damage so ascertained to the owner or owners, occupier or occupiers thereof: and upon payment being made by the said trustees, out of the money arising from the conversions imposed by this act, of the sum awarded to the party or parties interested, or consignation of the said sum in any of the public banks of Scotland, the said trustees shall from thenceforth have right, and be at liberty to take and use the ground, and to pull down the houses or fences so valued, for the purpose of alter-

ing, widening, and extending the highways aforesaid, as fully and effectually ever after, to all intents and purposes, as if the owner or owners of such grounds had executed regular dispositions of the same, and thereupon infeftments had followed; and the said proceedings and orders of the sheriff depute, or his substitute, shall be final, and not removable or questionable, by bills or letters of advocation or suspension, to or by any other court whatever: provided always, that the said jury, in assessing such value and damages, shall have power to take under their consideration all the advantages and disadvantages arising to the said owners and occupiers, by the altering or widening any of the said roads.

LI. And be it further enacted, that in altering the course of the said roads, or widening the same, it shall be in the power of the said trustees, or any three or more of them, in their respective districts, to make the same through any minister's glebe; provided always, that damages are paid to the minister or ministers, and that such quantity of ground shall be added to the glebe, lying most contiguous and convenient thereto, as shall be deemed a sufficient compensation for that taken for the said roads, which the said trustees shall have power to purchase from the contiguous owner or owners, occupier or occupiers of land; and the owner or occupier shall be obliged to sell, and in case of any difference with regard to the damages to be paid to such minister or ministers, or the addition to be made to such glebe, or the price to be paid to such owner or owners, occupier or occupiers of land, application shall be made to the sheriff depute of the said county, or his substitute, who shall proceed to summon a jury, and to determine and adjudge the amount thereof in manner as herein-

before in similar cases is directed; and upon payment being made by the said trustees of such damages to the minister or ministers, and of such price to the owner or owners, occupier or occupiers of land, and consignation thereof in any of the public banks of Scotland, the said trustees shall from thenceforth have right to be at liberty to take and use that part of the glebe for the purpose of altering or widening the said roads, fully and effectually, ever after, to all intents and purposes; and the proceedings and order of the said sheriff depute, or his substitute, shall be final and conclusive.

LII. And be it further enacted, that the said trustees, or any three or more of them, or such person or persons as they shall appoint, may dig, gather, take, and carry away gravel, furze, heath, stones, or such like materials, out of the several grounds of any person where materials may be found, not being dug or raised for the private use of the proprietor of such grounds, for making, repairing, and amending the said roads, or for building arches and bridges as aforesaid, and to open accesses for carrying off the said materials, such accesses, and the places from which the said materials shall be proposed to be taken, being first marked out by any three or more of the said trustees, if so required by the said proprietor of such grounds, or his or her factor, or by the occupier thereof, they the said trustees making reasonable satisfaction out of the money arising by virtue of this act, to the owners or occupiers of the grounds respectively from which such materials shall be taken, or over which the same may be carried, for the damages to be done thereby; but if such proprietor, factor, or occupier shall not be satisfied with the compensation offered by the said trustees, the same shall be ascertained by a jury,

to be impannelled by the sheriff depute, or his substitute, in the same manner as herein-before directed for determining the value of the houses or fences found necessary to be pulled down, or ground to be taken for altering or widening the said roads, or for valuation of old roads; which proceedings shall, in like manner, be final; but such application shall not prevent the said trustees from causing said materials to be carried off and used in the mean time; and in case the said jury shall find that the compensation which had been offered by the said trustees to the person or persons applying to the sheriff, was adequate to the damages they may have sustained, then, and in that case, such person or persons shall be liable in payment to the trustees of such a sum, in lieu of costs, as the said jury shall judge reasonable.

APPENDIX, No. VI.

The following Tables have been taken from the Report of the Committee of the House of Lords on Turnpike Road Trusts (1833).

STATEMENT of the present INCOME and EXPENDITURE of the TURNPIKE ROADS, by MR. MICHAEL IRISH.

Taken from the Abstract of the Turnpike Road Accounts for 1829, ordered to be printed by the House of Lords 1833.

	£ s. d.		£ s. d.	£ s. d.	£ s. d.	
Mortgage Debt -	6,578,815 2 11	On which the Interest was paid	5,093,410 2 11	236,629 9 8	0 0 0	Brought into Account in the 9th Column in the Returns.
		On which the Unpaid Interest was brought into Charge in the Returns - -	1,485,405 0 0	0 0 0	65,271 1 3	
Floating Debt -	303,541 13 9	On which no Interest was charged in the Returns -	303,541 13 9	0 0 0	15,172 0 0	Not brought into Account.
Unpaid Interest -	821,586 19 7	Ditto - - -	821,586 19 7	0 0 0	45,079 0 0	
Balances due to Treasurers -	81,227 8 11	Ditto - - - -	81,227 8 11	0 0 0	4,061 0 0	
TOTAL DEBT	£7,785,171 5 2	- - - -	£7,785,171 5 2	236,629 9 8	129,583 1 3	Actual Interest of the Debt not brought into Account in the Returns.

	£ s. d.		£. s. d.	
Debt whereon the Interest was paid	5,093,410 2 11	- -	236,629 9 8	Part paid, and brought into Account in the 9th Column in the Returns.
Debt whereon no Interest was paid	2,692,171 2 3	- - -	129,583 1 3	
TOTAL DEBT -	£7,785,581 5 2	TOTAL INTEREST, paid and unpaid	366,212 10 11	

	£	s.	d.	£	s.	d.
Tolls received - -	1,309,014	12	6	1,348,557	0	7
Tolls due, but unpaid	39,542	8	1			
Parish Composition received -	59,915	11	4	167,799	10	10
Ditto due, but unpaid -	7,883	19	6			
Ditto, supposed Value of Work performed by Parishes -	100,000	0	0			
Fines - - - -				288	5	4
Incidental Causes - - -				38,648	8	1
Total -				£1,555,293	4	10

	£	s.	d.	£	s.	d.	£	s.	d.	
Interest on Debt	-		-	-	-	-	366,212	10	11	Unpaid Interest is added
Manual Labour	-	-	-	303,173	4	0	495,919	0	5	
Team Labour	578,237	9	3	192,745	16	5				
One Third supposed Manual Labour -	192,745	16	5							
Residue, Team Labour, and some Improvements -	385,491	12	10							
Team Labour, as above - - - - -							385,491	12	10	
Land purchased, &c. - - - -							56,263	18	1	
Repairs, &c. - - - - - -							63,968	9	10	
Salaries, &c. - - - - - -							196,025	0	11	
Repairs and Statute Duty done by Parishes, and not brought into Charge - - - - -							100,000	0	0	
Payments, &c. (including Acts of Parliament, and Improvements above 100*l.*) - - - - - -							243,757	2	4	
Total - - £							1,907,637	15	4	

	£	s.	d.	
Expenditure -	1,907,637	15	4	Includes Statute Duty and Interest not brought into Charge.
Income - -	1,555,293	4	10	
	352,344	10	6	Expenditure above Income, taking the Gross, and Interest not brought in Charge being added.

1821 and 1829.

Comparative Statements of the above Years.

1821.		1829.		
Trusts - - -	1,025	Trusts - -	1,119	Increase, 94.
Miles* - - -	20,875	Miles - - -	19,798	Decrease, 1,077.
Acts of Parliament - -	2,485	Acts of Parliament -	3,783	Increase, 1,298.
Debts - -	£5,330,493	Debts - -	£7,785,171	Increase, £2,454,678.
Income - -	£1,088,767	Income - -	£1,455,293	Increase, £366,526.
Expenditure -	£1,034,124	Expenditure - -	£1,678,054	Increase, £643,930.
Income above Expenditure -	£54,643	Expenditure above Income -	£44,276	—
Debts per Mile - -	£255	Debts per Mile - -	£392	Increase, £137 per Mile.
Income per Mile - -	£52	Income per Mile - -	£73	Increase, £21 per Mile.
Expenditure per Mile -	£50	Expenditure - -	£85	Increase, £34 per Mile.

* Miles. — From the Manner in which the Account of 1821 was made up, it is not improbable that the Distance was computed, instead of being taken by Admeasurement.

NOTES.

NOTES.

Note A. Page 50.

HOLYHEAD ROAD.

STOWE VALLEY IMPROVEMENT.

*Investigation of the best Plan to be adopted for improving the Road through Stowe Hill Valley. By John Macneill.**

In a great public work of this kind, where a considerable sum of money is to be laid out, it becomes of the greatest importance to ascertain not only what would be the best plan to be adopted, but also to what extent it should be carried, or, in other words, what sum of money should be laid out on the works so as to produce the most advantageous result.

Without altering the entire line of road, as originally proposed by Mr. Telford, which would unquestionably have been the wisest measure, there does not appear to be any means of effecting an improvement of the present line of road, except by embanking across the valley, or lowering the ridges, or by both.

It is evident that each of these plans will admit of

* This paper, which was prepared for the Parliamentary Commissioners, was, with their permission, read at the Institution of Civil Engineers.
This and the following notes have been furnished by Mr. Macneill.

different degrees of perfection, according to the sum of money expended on the works; but it is not evident which of these plans is the best, nor does it follow that the same sum of money would produce an equally beneficial improvement, if laid out in raising the valley without lowering the summits, or in lowering the summits without raising the valley. In order to solve this important problem, and to arrive at an accurate result in this and similar investigations, it is necessary to know correctly the expense of horse labour under the varying circumstances of velocity and force of traction on different inclined planes, and also the draught of carriages, and the ratio of the increase of draught in consequence of increase of velocity.

By the experiments lately made on the Holyhead Road by order of the Parliamentary Commissioners, these circumstances have been accurately ascertained from practical experience, which has enabled me to deduce the necessary formulæ from actual practice, without having recourse to theoretical investigations or abstruse calculations.

To go into the detail by which these formulæ were deduced would be in this place unnecessary; it is sufficient to state that correct tables have been calculated from these formulæ, which show the expense of drawing a given weight with a given velocity over every rate of acclivity and declivity, and length of inclined plane.

By means of these tables the expense of drawing a ton weight over any line of road may be determined with great accuracy. Hence all that is necessary in the present investigation is, to calculate by the tables the expense of transporting a ton weight over the existing line of road, and also over the proposed improvements.

The difference will be the saving in expense of drawing one ton with the given velocity over the proposed improvement. This, multiplied by the number of tons that pass over the road each day, and by the number of days in the year, will give the annual saving, which, compared with the interest of the money necessary to be expended in making the improvement, will clearly show whether the saving in horse labour is commensurate with the proposed expense. By applying the same criterion to each of the proposed plans, it will at once be made evident which of them should be adopted, as that which would produce the most beneficial result at the smallest expense. By this method, which is new, and founded on correct principles, I have endeavoured to determine the most advantageous method of improving the present line of road across the Stowe Hill Valley from the sixty-fifth milestone to the Crown public-house at Foster's Booth, a distance of two miles.

Plan, No. I.

By this plan it is proposed to leave the present road near the sixty-fifth milestone, and to pass at an elevation of twenty-seven feet lower than the present road: from thence it would descend through a natural valley at a rate of inclination of one in thirty to an angle in the Lichborough and Northampton road: from this point it would pass in a straight and horizontal line, at an elevation of fifty feet over the brook, to the junction of the present road; here it would cross the road, and, skirting along the side of the hills at an inclination of one in thirty, running nearly parallel to the present road, and at about fifty yards distance from it, would pass the summit at twenty-seven feet lower level, and join the present road, near the Crown public-house.

For the purpose of ascertaining the comparative merit of this plan, the following calculation, as above described, has been made: —

Pages 411. and 412. contain the calculation of the expense of drawing one ton over the present line of road between the given points, in both directions; which amounts to 82·0647 pence.

Page 413. contains the calculation of expense of drawing one ton over the proposed improved road, as above described, between the same points; which amounts to 76·1724 pence. By this it appears that the saving in horse labour on each ton will be 5·8923 pence; and for 170 tons the daily saving will be 4*l.* 3*s.* 6*d.*, which, at 5 per cent., is interest for 30,310*l.* 10*s.* The estimate for making this improvement is 23,757*l.* (See page 418.)

The difference between the amount of the estimate and the saving to the public by the proposed improvement is, therefore, 6553*l.*, which is the actual sum the public would gain by this improvement, supposing the present traffic to continue; if the traffic increased, the saving would be still more.

Plan, No. II.

By this plan an embankment is proposed to be raised across the valley, 70 feet high, and 1313 yards long, the embankment to be formed with earth taken from the most convenient place, without having recourse to cutting from the summits: by this plan part of the present road would be retained.

By a calculation similar to that in the first investigation, and given in pages 413. and 414., it appears that the mean expense of drawing a ton between the sixty-fifth milestone and the Crown Inn, at Foster's Booth, would be 79·4584 pence; and as *the expense* of drawing a ton over the

present road between the same points is 82·0647 pence, the saving in expense by this improvement would be 2·6053 pence, and for 170 tons it would be 1*l.* 16*s.* 11*d.*, which is interest for 16,394*l.* The estimate for this improvement, as detailed in p. 419., is 28,890*l.* The difference between this sum, and the saving, is 12,496*l.* which is the loss the public would sustain by making this alteration, calculated on the present state of the traffic over the road.

Plan, No. III.

By this plan it is proposed to raise the valley fifty feet, to cut twenty-seven feet from the summit at Foster's Booth, and reduce the inclination from 1 in 16, 17, and 18, to 1 in 30, on the east side of the valley; and from 1 in 14 and 15 to 1 in 30 on the west side of the hill.

The embankment would commence near the sixty-fourth milestone, and terminate at the turn of the road leading to Northampton. The mean expense of drawing a ton weight over the road, when improved in this manner, between the sixty-fifth milestone and the Crown Inn at Foster's Booth, as given at p. 415., would be 78·4715 pence: here the saving would be 3·5942 pence on each ton, and for 170 tons it would be 2*l.* 10*s.* 11*d.*, which is interest for 18,483*l.*

The estimate for this work, as detailed in p. 420., is 20,144*l.*; the loss would therefore be 1661*l.* in making this alteration.

Plan, No. IV.

By this plan it is proposed to raise the valley forty feet, to cut twenty-seven feet from the summit at Foster's Booth, and ten feet from the summit at the Angel. The embankment would extend from near the turn of

the road to Lichborough to the upper angle of Mr. Drayson's osier plantation, and the lowering of the summit at Foster's Booth would extend into Cold Higham Fields, nearly similar to that in the first plan. All the rest of the road would remain as at present.

If this improvement were made, the mean expense of drawing one ton over it between the sixty-fifth milestone and the Crown Inn at Foster's Booth, would be 79·8450 pence, as shown in p. 416.: the saving, therefore, per ton, would be 2·2207 pence, and for 170 tons it would be 377·5190 pence; which would be interest for 11,420*l.*

The estimated expense of this improvement, as detailed in p. 421., is 14,171*l.* The difference is 2,751*l.*; which shows the amount of loss the public would sustain by completing the work here described.

Plan, No. V.

By this plan it is proposed to raise the valley forty feet, to lower the summit at Foster's Booth twenty-seven feet, and the summit at the Angel eighteen feet. If this improvement was adopted, the new line would run along the south side of the present road to near the sand pits, where it would cross it obliquely, and entering a small ravine on the opposite side, it would cross the valley in a straight line for the upper angle of the osier plantation. At this point it would again cross to the south side of the present line, and follow the direction described in the first plan.

The saving in expense of drawing a ton over this line of road, when made as above described, would be 5·0200 pence (p. 417.), and for 170 tons it would be 475·39 pence, which would be interest for 25,815*l.*

The estimated expense of this improvement, as

detailed in p. 422., is 19,607*l.* The difference is 5,208*l.*, which shows the amount of profit the public would acquire by completing the works here described.

Expense of drawing one ton by a stage coach over the present line of road from the sixty-fifth milestone to the Crown Inn at Foster's Booth.

Length.	Rates of Inclination.	Expense.	Length.	Rates of Inclination.	Expense.
300 r.	1 in 43	1·5246	200 r.	1 in 42	1·0200
300 r.	— 82	1·3872	500 r.	— 22	3·0415
200 r.	— 82	·9248	300 r.	— 20	1·8927
200 r.	— 40	1·0302	170 r.	— 43	·8639
100 r.	— 17	·6774	500 r.	— 97	2·2735
300 r.	— 14	2·2539	830 r.	— 24	4·8978
100 r.	— 15	·7223	220 r.	— 24	1·2982
210 r.	— 15	1·5168	100 r.	— 18	·6597
130 r.	— 31	·7112	200 r.	— 19	1·6754
200 r.	— 173	·8724	300 r.	— 23	1·7967
200 f.	— 197	·7808	300 r.	— 18	1·9791
500 f.	— 66	1·6880	300 r.	— 17	2·0322
350 f.	— 48	1·0797	200 r.	— 16	1·3960
500 f.	— 36	1·5425	200 r.	— 18	1·3194
200 f.	— 29	0·6170	400 r.	— 24	2·3604
300 f.	— 21	·9255	500 r.	— 34	2·6730
300 f.	— 21	·9255	800 r.	— 64	3·8120
300 f.	— 20	·9255	200 r.	— 36	1·0550
200 f.	— 22	·6170	300 r.	— 20	1·8927
300 f.	— 20	·9255	500 r.	— 34	2·6730
200 f.	— 20	·6170	250 r.	— 19	1·6110
300 f.	— 20	·9255	160 r.	— 30	·8828
300 f.	— 20	·9255	250 r.	— 34	1·3365
300 f.	— 20	·9255	300 r.	— 72	2·1333
300 f.	— 20	·9255	250 f.	— 119	·9378
280 f.	— 19	·8638	400 f.	— 53	1·2340
200 f.	— 19	·6170	400 f.	— 37	1·2340
200 f.	— 18	·6170	200 f.	— 30	·6170
150 f.	— 24	·4627	130 f.	— 19	·4010
200 f.	— 33	.6170	300 f.	— 28	
300 f.	— 56	·9255	200 f.	— 78	·9255
170 r.	— 71	·7992	300 f.	— 78	·7046
190 f.	— 64	·6348	130	Horizontal	1·0569
					·5360
					Pence 85·7272

Expense of drawing one ton by a stage coach over the present line of road from the Crown Inn at Foster's Booth to the sixty-fifth milestone at Stowe Hill.

Length.	Rates of Inclination.	Expense.	Length.	Rates of Inclination.	Expense.
130	Horizontal —	0·5360	190 r.	1 in 64 —	·9053
300 r.	1 in 78 —	1·3950	170 r.	— 71 —	·5860
200 r.	— 78 —	·9300	300 r.	— 56 —	1·4571
300 r.	— 28 —	1·6878	200 r.	— 23 —	1·0770
130 r.	— 19 —	·8377	150 r.	— 24 —	·8851
200 r.	— 36 —	1·1036	200 r.	— 18 —	1·3194
400 r.	— 37 —	2·0968	200 r.	— 19 —	1·2888
400 r.	— 53 —	1·9592	280 r.	— 19 —	1·8043
250 f.	— 119 —	1·1172	300 r.	— 20 —	1·8927
300 f.	— 72 —	1·0377	300 r.	— 20 —	1·8927
250 f.	— 34 —	·7712	300 r.	— 20 —	1·8927
160 f.	— 30 —	·4936	300 r.	— 20 —	1·8927
250 f.	— 19 —	·7712	200 r.	— 20 —	1·2618
500 f.	— 34 —	1·5425	300 r.	— 20 —	1·8927
300 f.	— 20 —	·9255	200 r.	— 22 —	1·2166
200 f.	— 36 —	·6170	300 r.	— 20 —	1·8927
800 f.	— 64 —	2·6728	300 r.	— 21 —	1·8570
500 f.	— 34 —	1·5425	200 r.	— 21 —	1·8570
400 f.	— 24 —	1·2340	200 r.	— 29 —	1·1186
200 f.	— 18 —	·6170	500 r.	— 36 —	2·6375
200 f.	— 16 —	·6170	350 r.	— 43 —	1·7787
300 f.	— 17 —	·9255	500 f.	— 66 —	2·3725
300 f.	— 18 —	·9255	200 f.	— 197 —	·8666
300 f.	— 23 —	·9255	200 f.	— 173 —	·7744
260 f.	— 19 —	·8021	130 f.	— 31 —	·4010
100 f.	— 18 —	·3085	210 f.	— 15 —	·6478
220 f.	— 24 —	·6787	100 f.	— 15 —	·3085
830 f.	— 24 —	2·5605	300 f.	— 14 —	·9255
500 f.	— 97 —	1·8285	100 f.	— 17 —	·3085
170 f.	— 93 —	·5244	200 f.	— 40 —	·6170
300 f.	— 20 —	·9255	200 f.	— 82 —	·7116
500 f.	— 22 —	·5425	300 f.	— 83 —	1·0674
200 f.	— 42 —	·6170	300 f.	— 42 —	·9255
			Expense of one ton		78·4023
			Expense of one ton in the contrary direction		85·7272
					2)164·1295
			Mean expense of one ton	Pence	82·0647

Expense of drawing one ton by stage coach over the road, when improved as described in Plan, No. I.

From the Sixty-fifth Milestone to the Crown Inn, at F.B.			*From the Crown Inn, at F. B. the Sixty-fifth Milestone.*		
Length.	Rates of Inclination.	Expense.	Length.	Rates of Inclination.	Expense.
437 r.	1 in 65 —	9.4457	312 f.	1 in 473 —	5.7209
78	Horizontal —	1·4618	1091 f.	—— 30 —	15.2980
758 f.	1 in 30 —	10·6286	1135	Horizontal —	21.2700
1185	Horizontal —	21·2700	758 r.	1 in 80 —	19·0128
1090 r.	1 in 30 —	27·3650	78	Horizontal —	1.4618
312 r.	—— 47 —	5·9708	437 f.	1 in 65 —	6·6716
44 f.	—— 28 —	·6169	28	Horizontal —	·5247
44 f.	—— 78 —	·6606	66 r.	1 in 78 —	1·3949
66 f.	—— 78 —	·9909	44 r.	—— 78 —	·9299
28	Horizontal —	·5247	44 r.	—— 28 —	1·12521
		78·9350		Pence	73·4098
					78·9350
					2)152·3448
			Mean expense of one ton }	Pence	76·1724

Expense of drawing one ton by a stage coach over the road, when improved as described in Plan, No. II.

From the Sixty-fifth Milestone to the Crown Inn.			*From the Crown Inn to the Sixty-fifth Milestone.*		
Length.	Rates of Inclination.	Expense.	Length.	Rates of Inclination.	Expense.
300 r.	1 in 43 ——	1·5246	130	Horizontal ——	·5360
300 r.	—— 82 ——	1·3872	300 r.	1 in 78 ——	1·3950
200 r.	—— 82 ——	·9248	200 r.	—— 78 ——	·9300
200 r.	—— 40 ——	1·0300	300 r.	—— 28 ——	1·6878
100 r.	—— 17 ——	·6774	130 r.	—— 19 ——	·8377
100 r.	—— 14 ——	2·2539	200 r.	—— 30 ——	1·1036
100 r.	—— 15 ——	·7223	400 r.	—— 37 ——	2·0968
210 r.	—— 15 ——	1·5168	400 r.	—— 53 ——	1·9592
130 r.	—— 31 ——	·7112	250 r.	—— 119 ——	1·1172
200 r.	—— 173 ——	·8724	300 f.	—— 72 ——	1·0377

TABLE — *continued.*

From the Crown Inn to the Sixty-fifth Milestone.			*From the Sixty-fifth Milestone to the Crown Inn.*		
Length.	Rates of Inclination.	Expense.	Length.	Rates of Inclination.	Expense.
200 f.	1 in 197 ——	·7808	250 f.	1 in 34 ——	·7712
500 f.	—— 66 ——	1·6880	160 f.	—— 30 ——	·4936
350 f.	—— 43 ——	1·0797	250 f.	—— 19 ——	·7712
500 f.	—— 36 ——	1·5425	500 f.	—— 34 ——	1·5425
200 f.	—— 29 ——	·6170	300 f.	—— 20 ——	·9255
300 f.	—— 21 ——	·9255	200 f.	—— 36 ——	·6170
300 f.	—— 21 ——	·9255	800 f.	—— 64 ——	2·6728
300 f.	—— 20 ——	·9255	500 f.	—— 34 ——	1·5425
200 f.	—— 22 ——	·6170	400 f.	—— 24 ——	1·2340
300 f.	—— 20 ——	·9255	200 f.	—— 18 ——	·6170
200 f.	—— 20 ——	·6170	200 f.	—— 16 ——	·6170
5970	Horizontal ——	24·6143	300 f.	—— 17 ——	·9255
300 r.	—— 23 ——	1·7967	300 f.	—— 18 ——	·9255
300 r.	—— 18 ——	1·9791	300 f.	—— 23 ——	·9255
300 r.	—— 17 ——	2·0322	5970	Horizontal ——	24·6143
200 r.	—— 16 ——	1·3960	200 r.	—— 20 ——	1·2618
200 r.	—— 18 ——	1·3194	300 r.	—— 20 ——	1·8927
400 r.	—— 24 ——	2·3604	200 r.	—— 22 ——	1·2166
500 r.	—— 34 ——	2·6730	300 r.	—— 20 ——	1·8927
800 r.	—— 64 ——	3·8120	300 r.	—— 21 ——	1·8570
200 r.	—— 36 ——	1·0550	300 r.	—— 21 ——	1·8570
300 r.	—— 20 ——	1·8927	200 r.	—— 29 ——	1·1186
500 r.	—— 34 ——	2·6730	500 r.	—— 36 ——	2·6375
250 r.	—— 19 ——	1·6110	350 r.	—— 43 ——	1·7787
160 r.	—— 30 ——	0·8828	500 r.	—— 66 ——	2·3725
250 r.	—— 34 ——	1·3365	200 r.	—— 197 ——	·8666
300 r.	—— 72 ——	2·1333	200 f.	—— 173 ——	·7744
250 f.	—— 119 ——	·9378	130 f.	—— 31 ——	·4010
400 f.	—— 53 ——	1·2340	210 f.	—— 15 ——	·6478
400 f.	—— 37 ——	1·2340	100 f.	—— 15 ——	·3085
200 f.	—— 30 ——	·6170	300 f.	—— 14 ——	·9255
130 f.	—— 19 ——	·4010	100 f.	—— 17 ——	·3085
300 f.	—— 28 ——	·9255	200 f.	—— 40 ——	·6170
200 f.	—— 78 ——	·7046	200 f.	—— 82 ——	·7116
300 f.	—— 78 ——	1·0569	300 f.	—— 82 ——	1·0674
130	Horizontal ——	·5360	300 f.	—— 43 ——	·9255
		Pence 83·4388			Pence 75·4780
					83·4388
					2)158·9168
			Mean expense of one ton	}	Pence 79·4584

Calculation of the expense of drawing one ton from Foster's Booth to Stowe Hill, and from Stowe Hill to Foster's Booth, on the supposition of raising the valley fifty-feet, lowering the summit at Foster's Booth twenty-four feet, and reducing the slopes from 1 in 16, 17, and 18, to 1 in 27 on the south side of the hills, and from 1 in 14 and 15 to 1 in 30 on the north side of the hill, as described in Plan, No. III.

Length.	Rates of Inclination.	Expense.	Length.	Rates of Inclination.	Expense.
300 r.	1 in 43 —	1·5246	130	Horizontal —	0·5360
1730 r.	—— 30 —	9·5461	300 r.	1 in 78 —	1·3950
500 f.	—— 66 —	1·6880	200 r.	—— 78 —	·9300
350 f.	—— 43 —	1·0797	200 r.	—— 28 —	1·6878
500 f.	—— 36 —	1·5425	2970	Horizontal —	12·2453
200 f.	—— 29 —	·6170	300 f.	1 in 20 —	·9255
300 f.	—— 21 —	·9255	200 f.	—— 36 —	·6170
300 f.	—— 21 —	·9255	300 f.	—— 64 —	2·6728
300 f.	—— 20 —	·9255	500 f.	—— 34 —	1·5425
200 f.	—— 22 —	·6170	400 f.	—— 24 —	1·2340
300 f.	—— 20 —	·9255	2760 f.	—— 30 —	8·5146
200 f.	—— 20 —	·6170	3630	Horizontal —	14·9664
300 f.	—— 20 —	·9255	600 r.	1 in 20 —	3·7854
600 f.	—— 20 —	1·8510	300 r.	—— 20 —	1·8927
3630	Horizontal —	14·9664	200 r.	—— 20 —	1·2618
2760 r.	1 in 30 —	15·2297	300 r.	—— 20 —	1·8927
400 r.	—— 24 —	2·3604	200 r.	—— 22 —	1·2166
500 r.	—— 34 —	2·6730	300 r.	—— 20 —	1·8927
800 r.	—— 64 —	3·8120	300 r.	—— 21 —	1·8570
200 r.	—— 36 —	1·0550	300 r.	—— 21 —	1·8570
300 r.	—— 20 —	1·8927	200 r.	—— 29 —	1·1186
2970	Horizontal —	12·2453	500 r.	—— 36 —	2·6375
200 f.	1 in 28 —	·6170	350 r.	—— 43 —	1·7787
200 f.	—— 78 —	·7046	500 r.	—— 66 —	2·3725
300 f.	—— 78 —	1·0569	1730 f.	—— 30 —	5·3370
130	Horizontal —	·5360	300 f.	—— 43 —	·9255
From Stowe Hill to F. B.	Pence	80·8594	From F. B. to Stowe Hill.	Pence	76·0836
					80·8594
					2)166·9430
			Mean expense of one ton	Pence	78·4715

Calculation of the expense of drawing one ton by a stage-coach from the Crown Inn at Foster's Booth

to the sixty-fifth milestone, and from the sixty-fifth milestone to the Crown Inn at Foster's Booth, on the supposition of raising the valley forty-feet, cutting twenty-seven feet from the summit at Foster's Booth, and reducing the inclination on Lovell's Hill from 1 in 14 and 15 to 1 in 30, as described in Plan, No. IV.

Length.	Rates of Inclination.	Expense.	Length.	Rates of Inclination.	Expense.
300 r.	1 in 43 —	1·5246	130	Horizontal —	·5360
1730 r.	— 30 —	9·5461	300 r.	1 in 78 —	1·3950
500 f.	— 66 —	1·6880	200 r.	— 78 —	·9300
350 f.	— 43 —	1·0797	200 r.	— 28 —	1·6878
500 f.	— 36 —	1·5425	2970	Horizontal —	12·2453
200 f.	— 29 —	·6170	300 f.	1 in 20 —	·9255
300 f.	— 21 —	·9255	200 f.	— 36 —	·6170
300 f.	— 21 —	·9255	800 f.	— 64 —	2·6728
300 f.	— 20 —	·9255	500 f.	— 34 —	1·5425
200 f.	— 22 —	·6170	400 f.	— 24 —	1·2340
300 f.	— 20 —	·9255	200 f.	— 18 —	·6170
200 f.	— 20 —	·6170	200 f.	— 16 —	·6170
300 f.	— 20 —	·9255	300 f.	— 17 —	·9255
300 f.	— 20 —	·9255	300 f.	— 18 —	·9255
400 f.	— 20 —	1·2340	300 f.	— 23 —	·9255
3960	Horizontal —	16·3671	260 f.	— 19 —	·8021
650 r.	1 in 24 —	3·8357	100 f.	— 18 —	·3085
100 r.	— 18 —	·6597	650 f.	— 24 —	2·0052
260 r.	— 19 —	1·6754	3960	Horizontal —	16·3271
300 r.	— 23 —	1·7967	400 r.	1 in 20 —	2·5236
300 r.	— 18 —	1·9791	300 r.	— 20 —	1·8927
300 r.	— 17 —	2·0322	300 r.	— 20 —	1·8927
200 r.	— 16 —	1·3960	200 r.	— 20 —	1·2618
200 r.	— 18 —	1·3194	300 r.	— 20 —	1·8927
400 r.	— 24 —	2·3504	200 r.	— 22 —	1·2166
500 r.	— 34 —	2·6730	300 r.	— 20 —	1·8927
800 r.	— 64 —	3·8120	300 r.	— 21 —	1·8570
200 r.	— 36 —	1·0550	300 r.	— 21 —	1·8570
300 r.	— 20 —	1·8927	200 r.	— 29 —	1·1186
2970	Horizontal —	12·2453	500 r.	— 36 —	2·6375
200 f.	1 in 28 —	·6170	350 r.	— 43 —	1·7787
200 f.	— 78 —	·7046	500 r.	— 66 —	2·3725
300 f.	— 78 —	1·0569	1730 f.	— 30 —	5·3370
130	Horizontal —	·5360	300 f.	— 43 —	·9255
From Stowe Hill to F. B.	}	Pence 81·9941	From F. B. to Stowe Hill	}	Pence 77·6959
					81·9941
			Mean expense of one ton.	}	2)159·6900
					Pence 79·8450

Calculation of the expense of drawing one ton by a stage coach over the road, when improved, as described in Plan No. V.

From Stowe Hill to F. B.			*From F. B. to Stowe Hill.*		
Length.	Rates of Inclination.	Expense.	Length.	Rates of Inclination.	Expense.
437	1 in 65 r. ——	9·4457	286	1 in 85 r. ——	5·9879
758	—— 30 f. ——	10·6286	231	—— 130 r. ——	4·6431
1135	Horizontal ——	21·2710	1130	—— 30 f. ——	15·8448
1130	1 in 30 r. ——	28·3437	1135	Horizontal ——	21·2710
231	—— 138 f. ——	3·9951	758	1 in 30 r. ——	19·0129
286	—— 85 f. ——	4·6555	437	—— 65 f. ——	6·6716
44	—— 28 f. ——	·6169	28	Horizontal ——	·5247
44	—— 78 f. ——	·6606	66	1 in 78 r. ——	1·3949
66	—— 78 f. ——	·9909	44	—— 78 r. ——	·9299
28	Horizontal ——	·5247	44	—— 28 r. ——	1·1252
	Pence	81·1327		Pence	77·4060
					81·1327
					2)154·0914
			Mean expense of one ton . . .		77·0457

Plan, No. I.

Estimate of the expense of making a new line of road between Stowe Hill and Foster's Booth, by which the valley would be raised fifty-feet, and the greatest rate of inclination in any part would not exceed 1 in 30.

	£	s.	d.
To 266,524 cubic yards of earth-work, at 1s. - - -	13,326	0	0
To 24,238 cubic yards of earth-work, at 6d. - - - -	605	0	0
To 20 acres of land for site of new road and embankment, at 100l. per acre -	2,000	0	0
To 1135 yards of fences over the embankment, at 10s. - -	567	10	0
To 2935 yards of post and rail fences, at 6s. - - -	880	10	0
To 4070 yards of road-making, at 15s. - - -	3,052	10	0
To culverts, 8 feet wide, under embankments - - - -	616	0	0
To cross-drains - - -	50	0	0
To field-gates - -	100	0	0
To toll house and gates - -	400	0	0
	21,597	10	0
Contingencies, to cover unforeseen expenses - - - -	2,159	10	0
	£23,757	0	0

Plan, No. II.

Estimate of the expense of raising the valley seventy feet.

	£	s.	d.
To 668,512 cubic yards, of earth-work in the embankment, at 7*d*. -	19,498	5	4
To 25 acres of land to be purchased to supply earth for the embankment, at 100*l*. - - -	2,500	0	0
To 14 acres of land required for the site of the embankment, at 100*l*. -	1,400	0	0
To 1313 yards of fences over the embankment, at 10*s*. - -	656	10	0
To 1313 yards of road-making, at 15*s*.	984	15	0
To culvert, 8 feet wide, under embankment - - - -	824	0	0
To toll house and gates - -	400	0	0
	26,263	10	4
Contingencies - -	2,626	9	8
	£28,890	0	0

Plan, No. III.

Estimate of the expense of raising the valley fifty feet, lowering the summit at Foster's Booth twenty-seven feet, and reducing the slopes from 1 in 16, 17, and 18, to 1 in 30, on the east side of the valley; and from 1 in 14 and 15 to 1 in 30, on the west side of the valley.

	£	s.	d.
To 104,671 cubic yards of earth-work, at 1s. - - - - -	5,233	11	0
To 207,781 cubic yards of earth-work, at 7d. - - - - -	6,060	5	7
To 31,784 cubic yards of earth, at 6d.	794	12	0
To 13½ acres of land, to be purchased for the new lines of road and embankments, at 100l. per acre -	1,350	0	0
Ten acres of land to be purchased to supply earth for the embankments, at 100l. - - -	1,000	0	0
To 682 yards of fences over the embankments, at 10s. - - -	341	0	0
To 1766 yards of post and rail fence, at 6s. - - -	529	16	0
To 2450 yards of road-making, at 15s.	1,837	10	0
To culvert, 8 feet wide, under the embankment - - -	616	0	0
To cross-drains - - - - -	50	0	0
Field-gates - - - -	100	0	0
Toll house and gates - - -	400	0	0
	18,312	14	7
Contingencies - -	1,831	5	5
	£20,144	0	0

Plan, No. IV.

Estimate of the expense of raising the valley forty feet, cutting twenty-seven feet from the summit at Foster's Booth, and reducing the inclinations from 1 in 14 and 15 to 1 in 30 on the west side of Lovell's Hill.

	£	s.	d.
To 104,671 cubic yards of earth-work, at 1*s.* - - - - -	5,233	11	0
To 12,440 cubic yards from back cutting, at 9*d.* - - - - -	466	0	0
To 63,931 cubic yards from back cutting, at 7*d.* - - - - -	1,864	13	1
To 2611 cubic yards of earth from back cutting, at 6*d.* - - - -	65	5	6
To three acres of land to be purchased for supplying earth for embankment, at 100*l.* - - -	300	0	0
To twelve acres of land to be purchased for the site of embankments, and for the cutting at Foster's Booth and Lovell's Hill, at 100*l.* - -	1,200	0	0
To 616 yards of fences over the embankment, at 10*s.* - - -	308	0	0
To 1870 yards of post and rail fence, at 6*s.* - - - -	561	0	0
To 2486 yards of road-making, at 15*s.*	1,864	10	0
To eight feet cubic under embankment	520	0	0
To cross-drains - - -	50	0	0
To field-gates, &c. - -	50	0	0
To toll house and gates - - -	400	0	0
	12,882	19	7
Contingencies - - - -	1,288	0	5
	£14,171	0	0

Plan, No. V.

Estimate for the expense of raising the valley forty feet, cutting twenty-seven feet from the summit at Foster's Booth, and fourteen from the summit at Stowe Hill.

	£	s.	d.
To 198,200 yards of earth-work in embankments taken from the cuttings, at 1s. - - -	9,910	0	0
To 23½ acres of land for cuttings and embankments, at 100l. - - -	2,350	0	0
To 682 yards of fences on the embankments, at 10s. - - - - -	341	0	0
To 3374 yards of post and rail fences, at 6s. - - -	1,014	4	0
To 4055 yards of road materials, at 15s.	3,041	5	0
To 8 feet culvert under embankment -	520	0	0
To cross drains - - -	100	0	0
Field-gates - - -	150	0	0
Toll house and gates - - -	400	0	0
	17,824	9	0
Contingencies - -	1,782	11	0
	£19,607	0	0

General Abstract.

No. of Plan.	Estimate. £	s.	d.	Saving in Horse Labour. £	s.	d.	Saving to the Public. £	s.	d.	Loss to the Public. £	s.	d.
1.	23757	10	0	30310	10	0	6553	0	0			
2.	28890	0	0	16394	0	0	- - - - -			12496	0	0
3.	20144	0	0	18483	0	0	- - - - -			1661	0	0
4.	14171	0	0	11420	0	0	- - - - -			2751	0	0
5.	19607	0	0	25815	0	0	5208	0	0			

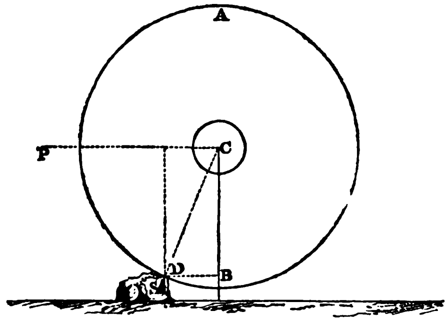
Note B. Page 65.

The resistance produced by collision is seldom a constant retarding force; loose stones, or hard substances, are sometimes met with, and will give a sudden check to the horses, according to the height of the obstacle: the momentum thus destroyed is often very considerable.

The power required to draw a wheel over a stone or other obstruction may be thus determined:—Suppose A B D to represent a carriage wheel 52 inches in diameter, the axis 2·5 inches in diameter, the weight of the wheel 200 lbs., and the load on the axle 300 lbs. Let a stone or other obstacle four inches high be represented as at S; the power necessary to be applied to the axle to draw the wheel over the stone is thus found:—Suppose P the power which is just sufficient to keep the wheel balanced, or in equilibrio, when acting from the centre C in the direction C P. The force acting against this power is gravity, and is equal to the weight of the wheel and load on the axle, acting from the centre C in the direction C B. These forces act together against the point D in the direction C D. Gravity acts in the direction C B with the energy or length of lever D B, and the power acts in the direction C P, with the leverage B C; and the equation of equilibrium will be $W \quad DB \quad P \times CB$. In this equation, C B the radius of the wheel diminished by the height of the obstacle, and B D equals $\sqrt{DC^2 - BC^2}$; hence the power $P = \dfrac{W \times \sqrt{DC^2 - BC^2}}{DC - DS}$: in the present example,

$W=500$; $DC=\frac{52}{2}=26$; $BC=DC-DS=26-4=22$; and $\sqrt{DC^2-BC^2}=13{\cdot}85$; the power, therefore, which is necessary to keep the whole in equilibrium, or resting off the ground, supported at the point D, will be equal to $\frac{500\times 13{\cdot}85}{22}=314{\cdot}3$ lbs.

The pressure at the point D is equal to the joint



action of the power and weight, as before stated, this in the present instance is represented by the radius of the wheel: hence $CB : CD :: 500 : \frac{CD\times 500}{CB}=\frac{26\times 500}{22}=591$ lbs. nearly. The injury which a road sustains by this pressure acting on a small point, and in an oblique direction, is very great: but it is not alone in this that the road suffers; the force with which the wheel strikes the surface, in its descent from the top of the stone, is considerable, and would soon wear a hole in the hardest road. But it must be observed, that a carriage mounted on proper springs will be drawn over an obstacle of this kind with much less power than if the carriage had no springs; for the springs allow the wheels to mount over the obstacle without raising the body of the carriage, and its load along with it, to the same height: upon this

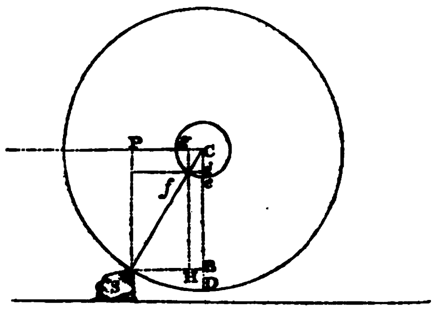
principle alone it is that carriages mounted on proper springs are easier moved than those without springs; and, for the same reason, springs are more necessary on rough and uneven roads than on smooth ones; and in proportion to the roughness of the roads should the springs be free and elastic; and it is to the improvement in the roads, of late years, that the rigid elliptic springs on carriages have been substituted for the C springs formerly in use; for, when ruts were very numerous, and the surface of the roads rough and uneven, the springs that are now used would have been of very little use, as their vertical motion is so limited, besides having no lateral play.

By enlarging the diameter of the wheel, the power required to draw it over an obstacle will be diminished; and, should the weight of the wheel remain the same, the power will decrease nearly as the diameter of the wheel increases: we have seen that, when the wheel was 52 inches in diameter (which is the general size of the front wheels of waggons), it required about 314 lbs. to keep the wheel in equilibrium when resting on a point four inches above the general surface. Suppose, now, that the hind wheel (the diameter of which is sixty-four inches) is to be pulled over the same obstacle, the power will be found to be only 305 lbs., although the weight is increased 70 lbs. by enlarging the wheel;

$$\text{for } P = \frac{W \times \sqrt{DC^2 - BC^2}}{DC - DS} = \frac{570 \times 15{\cdot}5}{28} = 305.$$

In this investigation we have supposed the power to act directly from the centre, and parallel to the horizon, which supposition is sufficient for practical purposes; but, if great accuracy be required, it will be necessary to allow for the thickness of the axletree, and to diminish the length of the lever by which the power and weight acts; for suppose the power to balance the weight, the

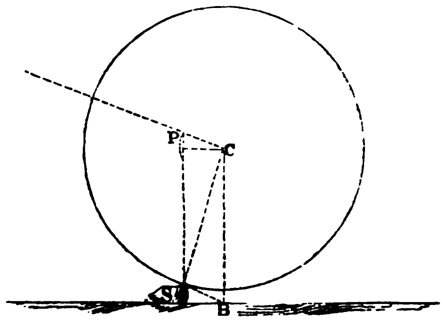
point of contact of the axle with the navewill be at half a right angle from the vertical line, or the arch $e f$



will be 45°, and f H will represent the force and direction of gravity, and S H that of the power; but f H is equal to C B—C i, and S H is equal to S B—$f i$, and because $f i$ C is a right angle $f i$ = C i. If the radius of the axle C F be 1·5 inches, the sine $f i$, or C i, of 45°, will be 1·06 inches: hence S H=S B—1·06=13·83—1·06=12·79, and f H=C B—$f g$=22—1·06=20·94; and the power $P = \frac{500 \times 12 \cdot 79}{20 \cdot 94} = 305 \cdot 4$ lbs.; which is 10lbs. less than that before found, without allowing for the diameter of the axle.

If the power be applied to the axle in a direction not parallel to the horizon, but inclining upwards, as represented in the following figure, the resistance will be diminished, or a less power will be required; for the leverage by which the power acts is increased, while the leverage by which gravity acts is decreased, until the line of draught forms a right angle with the line drawn from the centre of the axle to the point of contact, in which case the power is a minimum. On the contrary, if the direction of the line of draught be inclined downwards from the horizontal, the leverage by which it acts will be diminished, and consequently

the power must be increased as the direction of the line of draught falls below the horizontal.

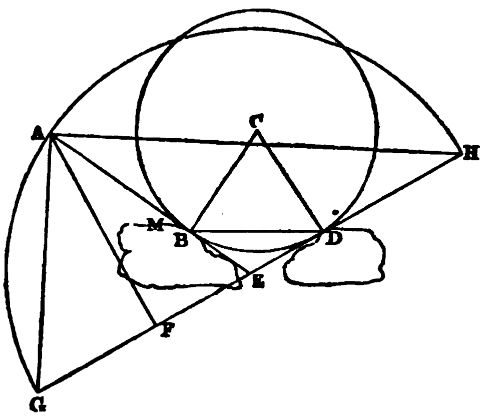


Formerly it was the practice to fasten on the streaks of iron, or shoeing, on the wheels of carriages with nails, the heads of which projected at least half an inch beyond the surface of the wheel. These heads formed a succession of obstacles over which the wheel had to mount; and, besides being extremely injurious to the roads, were a serious obstacle to the effective work of horses: the iron shoeing is now generally put on in hoops, and fastened by rivets, the heads of which are countersunk, and therefore form no impediment to the rolling of the wheel.

When the surface is indented, or furrowed into small cavities, such as a pebble pavement or badly dressed stone (into which the wheel falls, producing a shock the noise of which is well known), the resistance which is produced arises from a different cause. For the momentum or velocity in the horizontal direction is partly destroyed by the descent of the wheels into the hollows and the blow or collision against the opposite side of the cavity.

The resistance produced by such a surface has also been investigated by M. Gerstner. His reasoning may be briefly stated as follows:—

Suppose B E D one of the cavities formed by two contiguous stones.



Let the tangents B E and D E be drawn to the circumference of the wheel at the points of contact B and D, and suppose the velocity to be represented by A E = H E in magnitude and direction.

From the point E as a centre, and with the radius A E, describe the semicircle G A H, and let fall the perpendicular A F. The velocity A E may be resolved into two others, A F and F E: of these two, one, A F, is destroyed by the shock, and the other, F E, remains acting in the direction E D; consequently, the loss of velocity is equal to A E—E F=E G—E F=G F; and this loss must be compensated by an increase in the force of traction.

To avoid a complicated calculation, suppose the force of traction, K''', to be a constant accelerating force; Q, the weight of the carriage; and $2\,g\,t$, the velocity which gravity would generate in the weight Q at the end of the time t: we shall then have

$K'''=\frac{Q\cdot FG}{2\,g\,t}$. But FG : AG :: AG : 2AE; from which

$FG=\frac{AG^2}{2AE}$; and from the similar triangles A E G, DCB; AG : AE::DB : BC; from which $AG=\frac{AE\times DB}{BC}$; but $t=\frac{MN}{u}$; r representing the velocity with which the space M N is traversed in the time t. By making these substitutions, the former equation becomes $K'''=\frac{Q v^2}{4 g M N}\left(\frac{DB}{BC}\right)^2$.

From this expression the following conclusions may be drawn:—

1. That the resistance arising from a surface of this description is proportional to the load.

2. That the draught or force of traction is proportional to the square of the velocity; and consequently pebble or rough pavements are more adapted for heavy loads, with a slow velocity, than for light carriages with quick velocities.

3. That the draught increases in the inverse ratio of M N; that is, as the distance between the paving-stones diminishes, or as the stones are narrow, the cavities remaining the same.

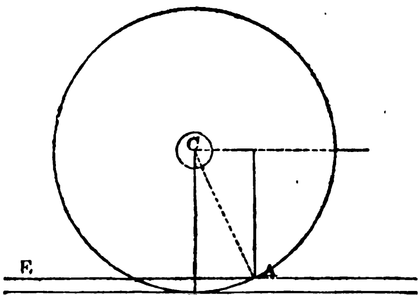
4. That the draught increases in the ratio of the width of the cavity to the radius of the wheel.

When the stones made use of for paving are of a good shape, well dressed, and sufficiently large, and laid on a firm and substantial foundation, they form the most perfect road surface for general purposes. The cavity between the stones should not exceed half an inch in width, by which means carriage wheels would pass over them without the least shock or resistance, and consequently without producing the noise often complained of in towns, at the same time that the surface would be sufficiently rough to prevent the horses from slipping.

Note C. Page 70.

The next resistance, friction, which we shall consider, is that which arises from the wheels being forced over obstacles which break down under their weight, or when they are drawn through mud or other soft substances, or when the material of which the road is composed (such as gravel or small stones) is put on a soft or yielding substratum in layers so thin that the weight of the wheel can make an impression on it, and force it down so as to form a rut.

Let A B C represent a carriage wheel resting on the



horizontal road B D, the surface of which is hard and solid, but covered with mud, sand, or gravel, to the height of the line A E: if it be very soft, the wheel, as it rolls along, will press through it as if it was water, and rest on the hard and firm surface B D. If it be of a more tenacious nature, as some clays, or composed of sand or gravel which the wheels will only compress, without displacing it, the wheel will not go to the hard

surface, but approach it in proportion to the weight on the axle or wheel and the compressibility of the material over which it passes. A heavy wheel will sink deeper than a light one into a soft road, if both wheels be of the same dimensions. At the point A, where there is no weight, the surface is undisturbed; and at the point B, the material composing the road is compressed and sunk as much as it can be by such a weight: all the intermediate part between A and B is pressed by a less weight, decreasing from B towards A, and is proportionally compressed or lowered. The resistance which is opposed to the wheel evidently arises from its action upon that portion of sand or mud contained between A and B; and the power necessary to overcome this will depend upon the length of lever at which it acts, or the depth to which the wheel sinks, and the stiffness or incompressibility of the substance which covers the road. Hence it is impossible to say or calculate the power or draught necessary to draw a carriage over a road so circumstanced, without experiments being made to ascertain the compressibility of each substance, and the consequent effect on the draught of carriages with wheels of different construction, and different loads. It is, however, within the power of mathematical investigation to furnish formulæ by which the law of increase in the power necessary to overcome such resistances is known, and by combining these with experiments the power necessary to draw a carriage over any line of road may be determined.

If the resistance arises from the wheel sinking into a soft stratum, instead of through an accumulation of mud or dust, until it rests on a firm surface, the investigation will be similar: the only difference is, that in one case the wheel can only sink a limited depth; for, arriving at the

hard surface of the road, it can penetrate no farther, the leverage at which the power acts will remain constant, if the weight be sufficient to press the wheel through the soft covering to the solid surface. The resistance will depend upon the nature of the material through which it rolls; but, if there be no solid or hard substratum under the outer crust, there will be no limit to the depth to which the wheel will sink. Thus, when a cart is drawn through a ploughed field, it is well known that the wheels will penetrate to a depth proportionate to the load, and the labour of the horses will be increased accordingly.

This effect is nearly the same as that which takes place when a carriage is drawn over a weak gravelly road, and is evidently more injurious to the horses employed in draught than when they work on a solid and firm road, although it be covered with an inch or two of mud.

M. Gerstner has investigated this subject, and given formulæ for the resistance arising from a wheel passing over a soft stratum of different degrees of compressibility. These formulæ are

$$K''=\frac{fq}{A}=\frac{q^2}{A\,h\,m};\ \text{when } m=o;$$

$$K''=\frac{3fq}{4A}=\tfrac{3}{4}q\sqrt[3]{\frac{3q}{2A^2bW}};\ \text{when } m=1;$$

$$K''=\frac{5fq}{8A}=\tfrac{5}{8}q\sqrt[5]{\frac{15q}{8A^3bm}};\ \text{when m}=2:$$

In which $K''=$ the resistance;

$f=$ half the chord of the segment of the wheel in the ground;

$A=$ radius of the wheel;

q = weight of load;
W = resistance of the soil when compressed by the wheel to the depth of an inch or any other unit;
m = an indeterminate number, expressing a power of the depth to which the wheel penetrates, proportional to the resistance of the soil at that depth, and which is to be determined by experiment.

From these formulæ it is evident that the resistance is caused by the wheels sinking into the ground; and therefore it will be better, under such circumstances, to divide a heavy load between two or more carriages than to carry a heavy load on one carriage; and also that the resistance will be diminished by increasing the width of the wheels.

the pressure of the carriage on the surface of the road, and that represented by A B is the force independent of friction, which acts against the carriage going up hill, or tends to force it down hill.

Note D. Page 76.

Now, this force may be found as follows:—The triangle A B C is similar to the triangle A K F; for the

When the road is not horizontal, a hill is a great impediment to the draught of carriages, and limits considerably the effect which would otherwise be produced by a horse in drawing a load.

If it were not for the hills that are usually met with on turnpike roads, one horse would do as much work as four; for it is well known that the force of draught must be increased in proportion to the steepness of hills; the quantity of that increase is thus determined.

Suppose a waggon resting on an inclined plane F G;

and let C be the centre of gravity of the waggon and load. Draw the line C B perpendicular to the surface of the hill, and C A perpendicular to the horizon; let this last line represent the force of gravity, or weight of the carriage and load. This force is equivalent to two others represented by the lines A B and C B in magnitude and direction. The force represented by C B is

the pressure of the carriage on the surface of the road, and that represented by A B is the force independent of friction, which acts against the carriage going up hill, or tends to force it down hill.

Now, this force may be found as follows:—The triangle A B C is similar to the triangle A K F; for the angle F A K = the angle C A B = the angle E G F; and the angle A B C and A K F are each right angles; therefore A C : A B : : F A : A K; but F A : A K as the length of the plane is to its height; that is, A C : A B :: l : h; and as the line A C represents the weight of the carriage, or W, we have W : A B :: l : h; or, $AB = \frac{Wh}{l}$ = the force represented by the line A B. The power required to draw a carriage on a horizontal may be represented by the formula $P = W\left(\frac{rm}{R} + \frac{3f}{4R}\right)$ for a broken stone road, and $P = W\left(\left(\frac{rm}{R}\right) + \frac{v^2}{4gMN}\left(\frac{DB}{BC}\right)^2\right)$ for a paved one.*

We then have, for the power required to draw a waggon or coach up an inclined plane, the formula $P = W\left(\frac{h}{l} + \frac{rm}{R} + \frac{3f}{4R}\right)$, if the surface be of broken stone; or $P = W\left(\frac{h}{l} + \frac{rm}{R} + \frac{v^2}{4gMN}\left(\frac{DB}{CD}\right)^2\right)$, if the surface be a pebble pavement; and for the power required to draw the same waggon down hill, the same formula, only making the sign of $\frac{h}{l}$ negative.

In these formulæ, W = the weight of the waggon wheels, and load: for although it might at first sight appear that we should make use of the weight on the

* See Mémoire sur les Grandes Routes, &c. de M. F. de Gerstner.

axle, or that represented by the line C B, to calculate the resistance, yet it is not so; for the pressure on the axles will be equal to the joint action of the weight on the axles and the moving power, and this will be the force represented by the line A C, or W, so that no correction of the weight is necessary.

The resistances arising from part of the weight being thrown from the front axles to the hind ones, in consequence of the inclination of the traces, and the line of draught not passing through the centre of gravity of the carriage, may be omitted in a general investigation, also the correction that should be applied to the resistances where the carriage is on an inclined plane; because it is evident that there is less weight on the surface than if the carriage stood on level ground, and also from the hind wheels bearing a greater pressure than the front ones, in consequence of the line of gravity falling nearer to the hind wheels, as the difference that will take place in the draught, in consequence of these, will be inconsiderable in general practice, and, should extreme accuracy be required in any particular case, it will be easy to make the necessary calculations.

The following experiments were made with the waggon, the axles and wheels of which had been previously made use of for the experiments on friction.

1. Half a ton of stone was put in the waggon, as nearly as possible in the centre between each axletree; the waggon was then drawn over a timber platform, perfectly horizontal, by weights suspended from a line: to effect this, it required 50¾ lbs.

2. A ton of stone was placed in the waggon, half a ton over each axletree, and the power required to draw the waggon over the same surface was 70 lbs.

3. A ton and a half of stone was placed in the wag-

gon, and distributed equally over each axletree; the weight or power required to draw the waggon was then found to be 90 lbs.

The resistances arising from the friction of the axletrees in the above experiments were then calculated for each wheel from the formula before given, and the total resistance arising from the axles, thus determined, was subtracted from the draught or power found by experiment as requisite to draw the waggon; the difference gave the resistance of the surface caused by the penetration of the wheels into the timber surface.

The results of these experiments are given in the following Table: —

Weight of Waggon and Load in Pounds.	Power required to draw the Waggon.	Resistance of the Axles.		Resistance of the Surface.
2240	31·0	13·0 10·6	23·6	7·4
2800	52·0	16·2 13·3	29·5	22·5
3360	70·0	19·5 15·9	35·4	34·6
3920	91·0	2·7 8·6	41·3	49·7

By a considerable number of experiments with the same waggon, on roads of different kinds, the draught

was found to agree very nearly with the results calculated from the empyrical formula

$$P=\frac{W+w}{93}+\frac{w}{40}+v;$$

In which W= the weight of the waggon; w, the load; c, a constant number, which will depend on the surface over which the waggon is drawn; and v, the velocity in feet per second. By putting $v=3\cdot7$, which was the velocity used in the foregoing experiments, the constant number for a timber surface was determined, and found to be equal to 2.

For other surfaces, the value of c may be taken as follows: —

On a paved road - - -	2
On a well-made broken stone road in a dry clean state - - - -	5
On a well-made broken stone road covered with dust - - - -	8
On a well-made broken stone road wet and muddy	10
On a gravel or flint road in a dry clean state -	13
On a gravel or flint road in a wet muddy state -	32

On an inclined plane the above formula becomes

$P=\frac{W+w}{93}+\frac{w}{40}+v+\frac{h}{l}\cdot\frac{W+w}{1}$; for a common stage waggon, and $P=\frac{W+w}{100}\times\frac{w}{40}\times\ c\ \frac{h}{l}\cdot\frac{W+w}{1}$ for a stage coach.

THE END.

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Printed by A. Spottiswoode,
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PLATE. II.

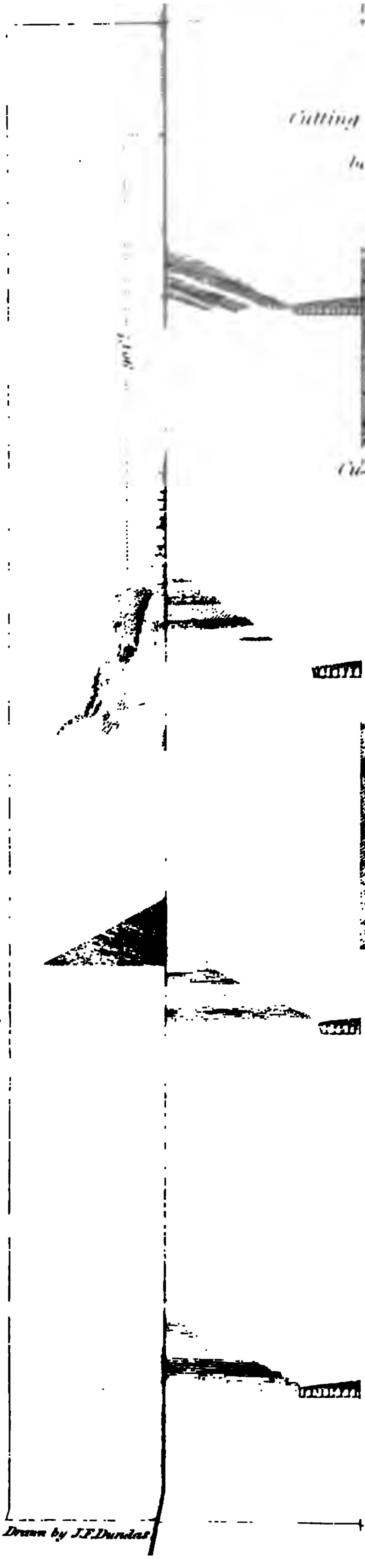


Fig. 10.

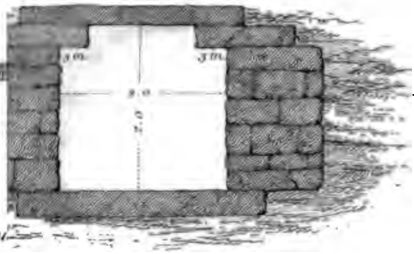


Fig. 11.

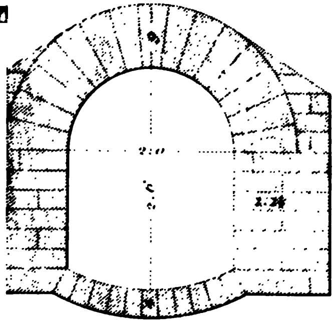
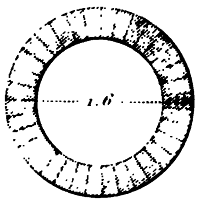


Fig. 12.



Drawn by J.F. Dundas

E. Turrell

PLATE. II.

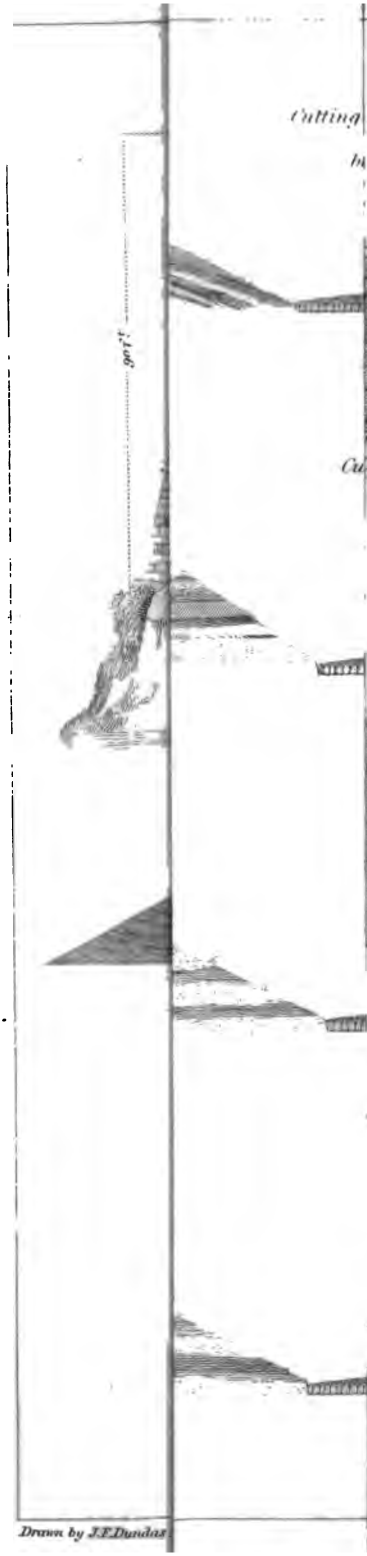


Fig. 10.

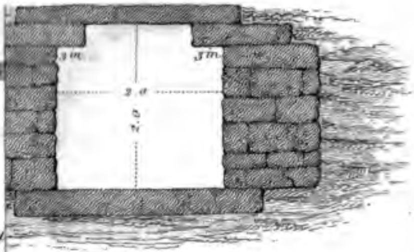


Fig. 11.

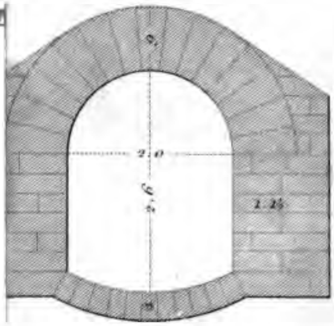
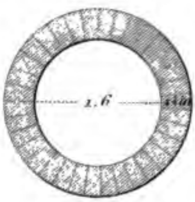


Fig. 12.



Drawn by J.F. Dundas

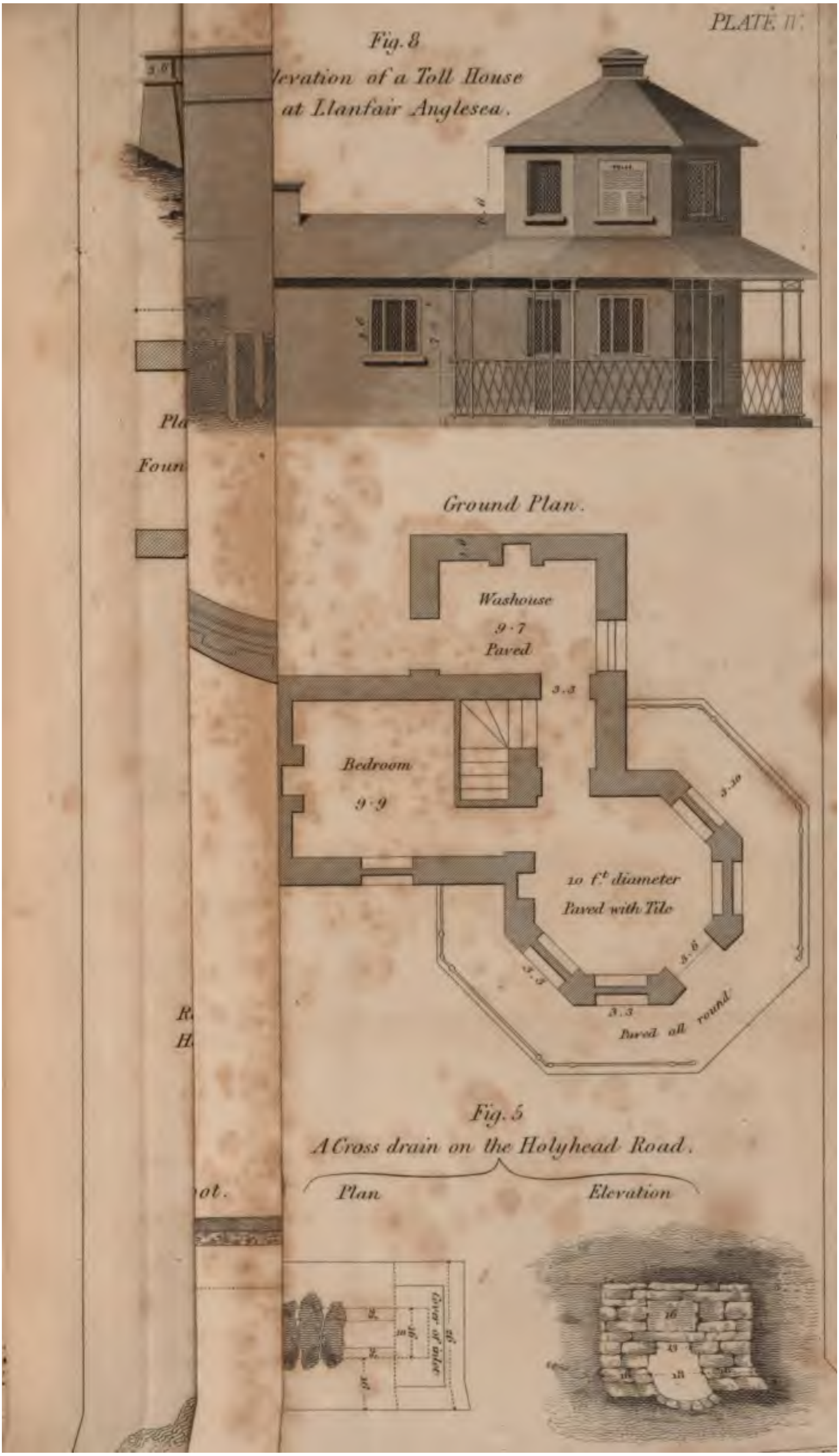


PLATE II.
Fig. 8
levation of a Toll House
at Llanfair Anglesea.
Ground Plan.
Washouse
9·7
Paved
Bedroom
9·9
10 f.t diameter
Paved with Tile
Paved all round
Fig. 5
A Cross drain on the Holyhead Road.
Plan
Elevation
Pla
Foun
ot.

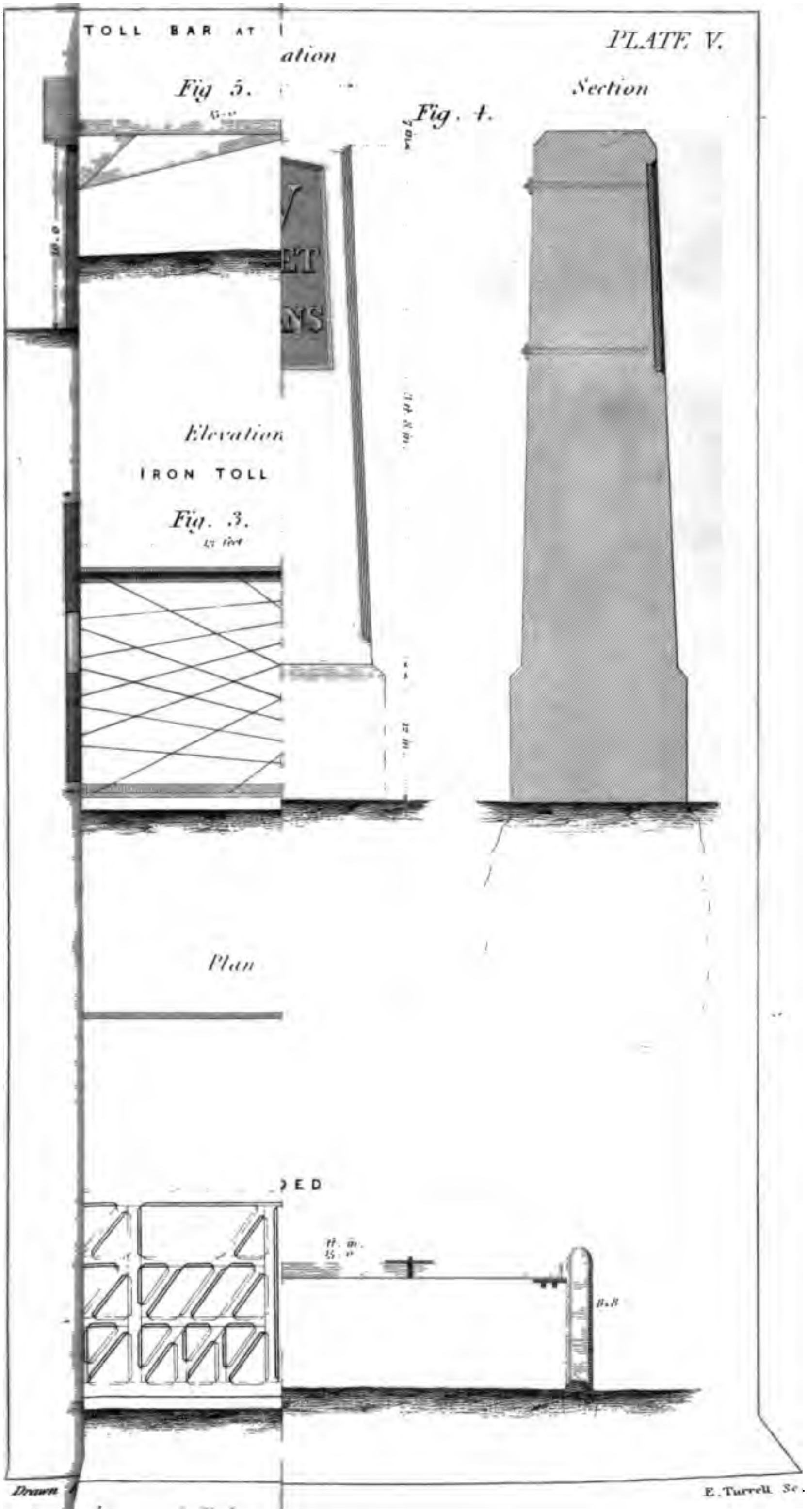


PLATE V.
TOLL BAR AT
ation
Fig 5.
Fig. 4.
Section
Elevation
IRON TOLL
Fig. 3.
Plan
Drawn
E. Turrell Sc.

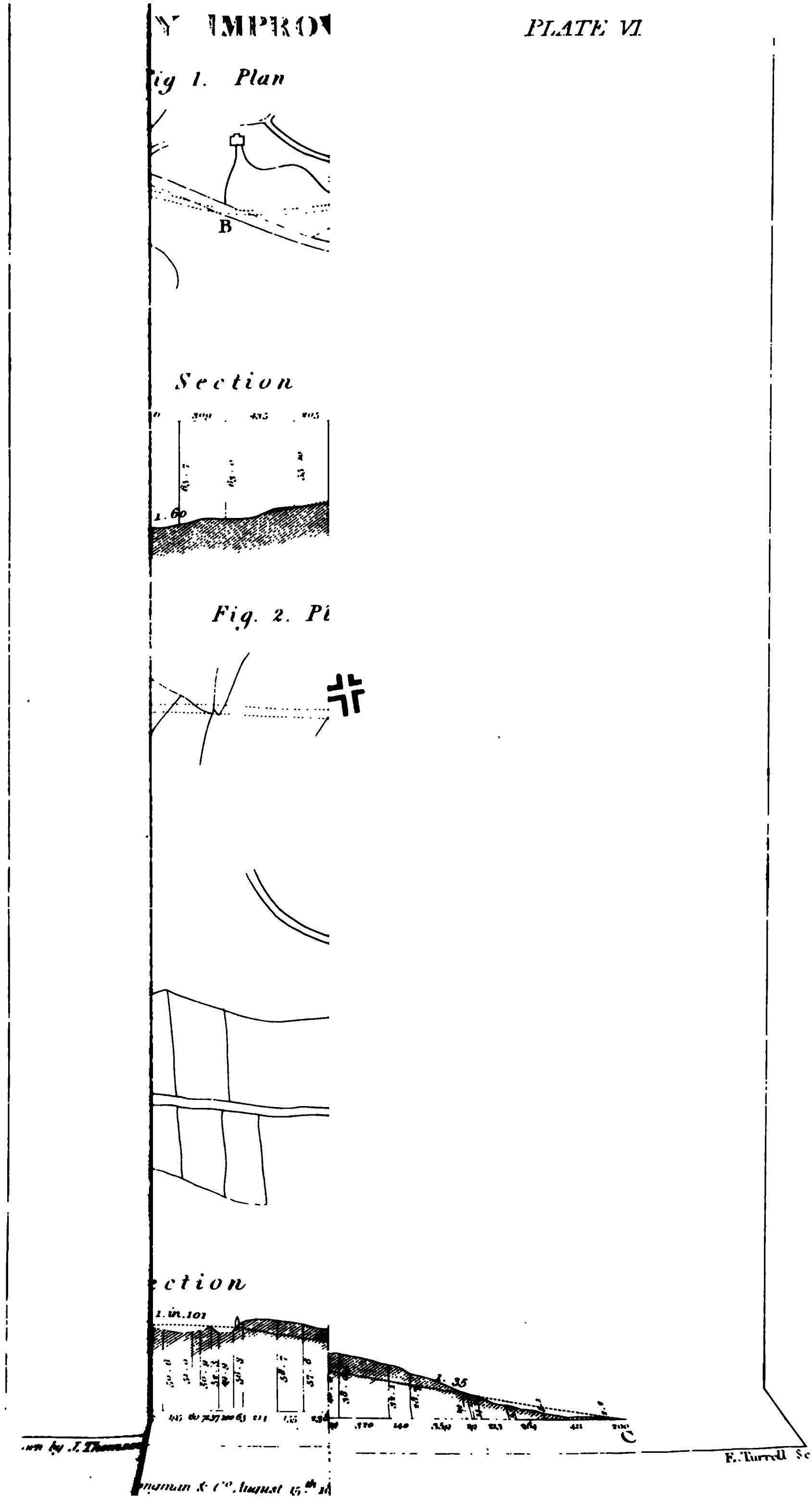
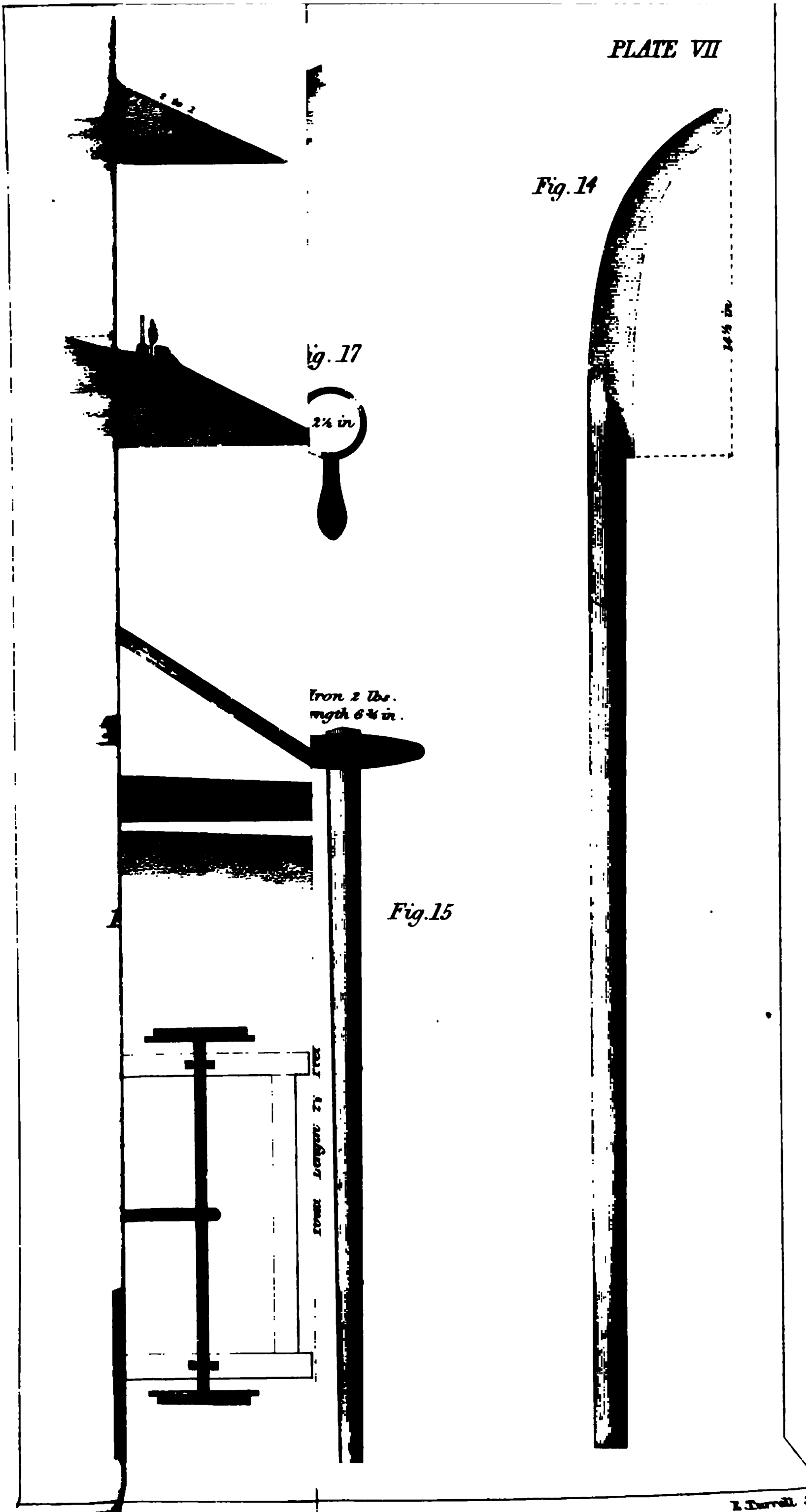

Y IMPRO
ig 1. Plan
B
Section
Fig. 2. Pl
ction
1. in. 101
1. 35
C
F. Turrell Sc

PLATE VII



Drawn by

I. Darrell

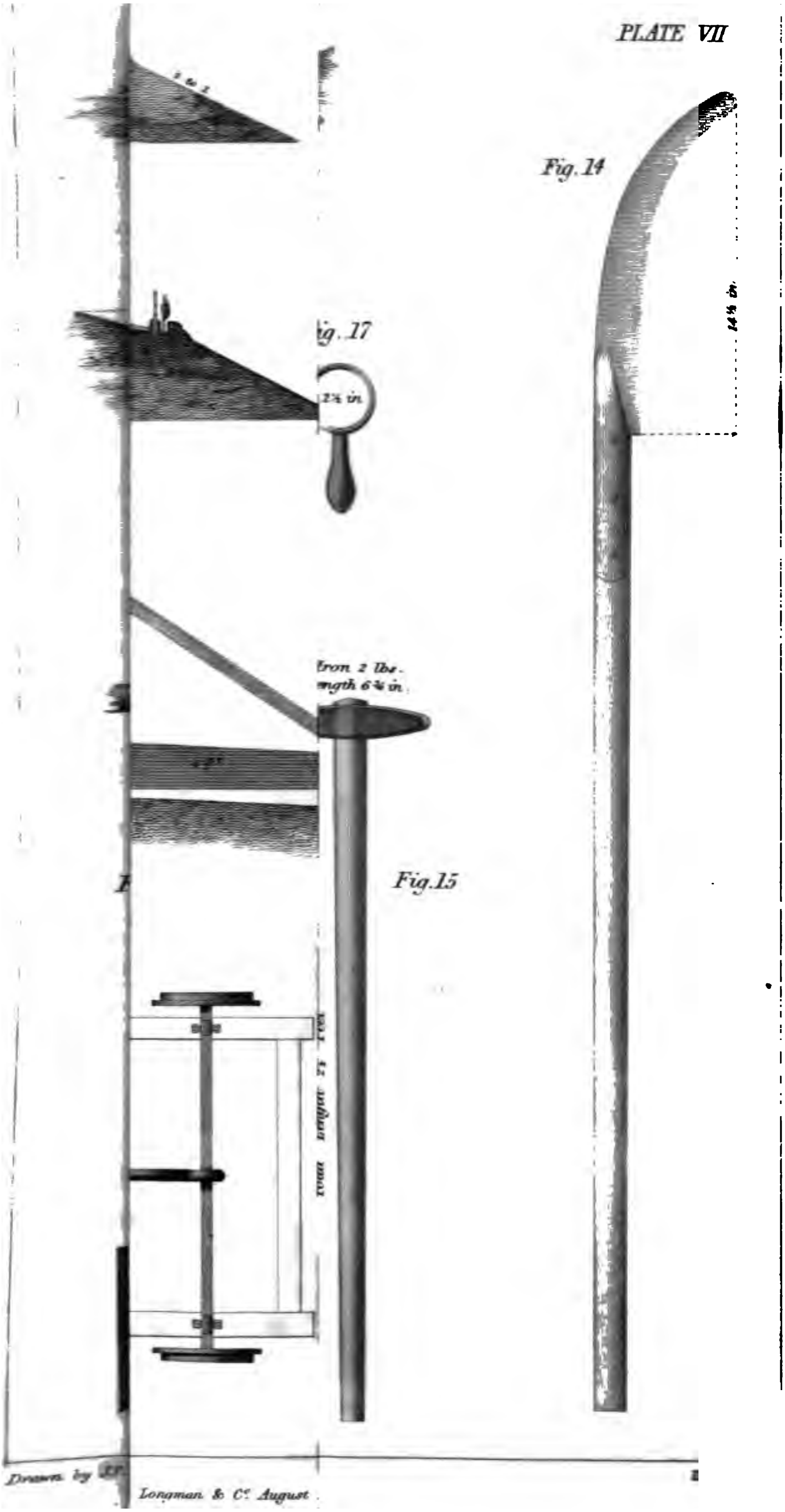


PLATE VII
Fig. 14
14½ in.
Fig. 17
2¼ in
Iron 2 lbs.
ngth 6¼ in.
Fig.15
Drawn by
Longman & Cº August